APPENDIX C

BMT WBM FLOOD REPORT AND OSD STUDY

A part of BMT in Energy and Environment

Evans River Flood Study - Final Report

Reference: R.B20500.001.03.Final_Report.docx

Date: November 2014

Evans River Flood Study - Final Report

Prepared for:	Richmond River County Council
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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	Client Reference:	
Synopsis:	**Evans River Flood Study**	

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
0	12/12/2013	BMC		BR	
1	14/03/2013	BMC		BR	
2	11/06/2014	BMC		BR	
3	19/11/2014	BMC		BR	

DISTRIBUTION

Destination	Revision										
	0	1	2	3	4	5	6	7	8	9	10
Richmond River County Council	PDF	PDF	PDF	PDF							
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Executive Summary

The Evans River is located within the Richmond Valley Council (RVC) local government area in the Northern Rivers region of NSW. Relative to the neighbouring Richmond River catchment (6,900km2), the Evans River has a small catchment (90km^2). However, the floodplains of the Richmond and Evans Rivers are linked, and during floods the Evans River receives floodwater from the Richmond. The Evans River provides a shorter flowpath for floodwaters to drain from the Mid-Richmond basin to the Pacific Ocean at Evans Head, hence is a critical part of the Richmond River system. In the late 1800's, the connectivity between the Richmond and Evans Rivers was formalised through construction of the Tuckombil Canal. Following two major events in the 1950's, the Tuckombil Canal was enlarged to its current form. A weir at the upstream end of the Tuckombil Canal prevents the more saline waters of the Evans River from entering Rocky Mouth Creek and the Richmond River. The Tuckombil Canal and associated weir have been a continued source of disagreement amongst the community as flood mitigation is balanced against prevention of tidal intrusion. The current fixed concrete weir structure has been demonstrated to provide a fair balance. Richmond River County Council (RRCC) is the floodplain management authority responsible for the Evans River catchment, working closely with RVC and the NSW Office of Environment and Heritage. Management of the Tuckombil Canal weir is the responsibility of RRCC.

Evans Head is the only town within the Evans River catchment and much of the town is high enough not be directly affected by flood events on the Evans River. However, to date, no study has been produced which has determined and mapped the flood risk along the entire length of the Evans River.

As part of this study, hydrologic and hydraulic modelling of the Evans River has been undertaken which has included development of a high resolution two-dimensional hydraulic flood model extending from Rocky Mouth Creek to the ocean. The hydraulic model incorporates LiDAR aerial survey captured by the NSW Department of Land and Property Information in 2010. The terrestrial survey has been merged with bathymetric data of the Evans River and Tuckombil Canal channels. Survey of key levees collected by RRCC in 2010 has also been included.

Inflows to the hydraulic model have been derived from the Richmond River flood model developed as part of the Richmond River Flood Mapping Study (BMT WBM, 2010) and since modified as part of other recent flood investigations on the Richmond River. The Richmond River flood model (hydrologic and hydraulic models) have previously been jointly calibrated and verified against various historical flood events. As such, a full calibration of the Evans River model has not been required. The two historical events of March 1974 and May 2009 have been used for verification of model performance. The model verification has shown that the model performs well in estimating the timing and peak flood levels and that the model is fit-for-purpose for use in defining design flood behaviour (i.e. levels, depths, velocities and hazard).

The 20, 50, 100, and 500 year ARI design flood events have been modelled and mapped along with the probable maximum flood (PMF). The Evans River hydraulic model uses a downstream time varying ocean boundary with a peak level of 2.0m AHD in the 100 year ARI event, which accounts for storm surge.

Modelling has shown that the upper parts of the Evans River catchment near the Tuckombil Canal are subject to extensive flooding. At Evans Head the overall risk to the community is low. However, some low lying parts of Evans Head such as the Silver Sands Caravan Park and parts of South Evans Head (including the harbour, Ocean Drive and Bundjalung Road) are at risk during major flood events (i.e. the 100 year ARI or greater).

A climate change assessment accounting for the effects of a 10% increase in rainfall intensity and a 0.9m increase in sea level has shown significant increases in flood levels in Evans Head. However, the overall extent of inundation is largely unchanged with much of the town remaining above the predicted 100 year ARI future flood level.

An additional assessment has been undertaken on local flood events caused by short, intense rainfall over the Evans River catchment (i.e. events with no flood inflows from the Richmond River). The assessment showed that, except for the uppermost headwaters, the predicted flood levels will be lower than those for when the Richmond River overflows into the catchment. The modelled design events which include the Richmond River inflows have therefore been selected for mapping the maximum flood extents.

A further assessment has been undertaken on travel times of a major (100 year ARI) Richmond River flood passing through the Evans River system. The analysis has showed that it takes approximately 5 hours for the peak to travel from the Tuckombil Weir to the ocean.

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Abbreviations

1D / 2D	One dimensional / two dimensional
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff (IEAust, 1987)
BoM	Bureau of Meteorology
BSC	Ballina Shire Council
DECCW	Department of Environment, Climate Change and Heritage (now OEH)
DEM	Digital Elevation Model
DNR	Department of Natural Resources
GIS	Geographical Information System
OEH	NSW Office of Environment and Heritage
LiDAR	Light Detection and Ranging (aerial survey technique)
km	Kilometre
MHL	Manly Hydraulics Laboratory
m	Metre
m/s	Metres per second
m AHD	Elevation in metres relative to the Australian Height Datum
NOW	NSW Office of Water
NPWS	National Parks and Wildlife Service
RRCC	Richmond River County Council
RVC	Richmond Valley Council
WBNM	Watershed Network Bounded Model hydrologic modelling software

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1 Introduction

1.1 Background

Evans River is located within the administrative area of Richmond Valley Council (RVC) and extends from the Tuckombil Canal in the west to the Pacific Ocean in the east. Relative to the neighbouring Richmond River catchment (6,900km^2), the Evans River has a small catchment (90km^2). Following the construction of the Tuckombil Canal in 1895 the catchment was linked to the much larger catchment of the Richmond River from which it receives flow during flood events on the Richmond River. Figure 1-1 shows the Evans River catchment and Figure 1-2 shows the topography of the catchment.

RRCC commissioned BMT WBM to undertake a flood study for Evans River which considers both flooding from local runoff generated within the Evans River catchment and flooding from the regional inflows which enter the catchment from the Richmond River. The purpose of the study is to use hydrologic and hydraulic modelling to quantify and map the flood risk with the Evans River, with a particular focus on the only main township within the catchment at Evans Head.

1.2 Study Objectives

The objectives for this study are to:

- Develop and calibrate a hydraulic model of the Evans River;
- Use the hydraulic model to define existing flood risk for design events ranging from a 20 year average recurrence interval (ARI) event to the probable maximum flood (PMF);
- Identify approximate travel times of the riverine flood along the Evans River;
- Identify any specific access issues to property during flood events;
- Identify any drainage infrastructure which may be undersized and cause flooding issues; and
- Assess the likely implications to flood risk under a future (2100) climate by considering sea level rise.

It is intended that Richmond Valley Council will incorporate the flood risk mapping into their Development Control Plans, as well as making the information publically available through the Richmond Valley interactive flood mapping website.

1.3 Past Investigations

There has been a range of studies undertaken of the Evans River, Richmond River and the Tuckombil Canal which connects the two. A brief summary of the more recent studies is listed below.

Coastal Zone Management Plan: Evans Head Coastline and Evans River Estuary (2013)

Completed by Hydrosphere Consulting in 2013 and subsequently adopted by Council in June 2013, the study provides a ten year strategic plan to implement key actions which achieve objectives for management of the Evans Head coastline and estuary. The objectives seek to balance long term utilisation of the coastline and estuary with its conservation.

Evans Head Coastline Hazard and Estuarine Water Level Definition Study (2012)

The study for Richmond Valley Council prepared by Worley Parsons updated a previous study completed in 2004 and defined coastline hazard lines for the existing climate as well as 2050 and 2100 climate scenarios. The study developed a 2D hydraulic model of the lower Evans River to determine the 100 year ARI flood level.

Richmond River Flood Mapping Study (2010)

This study undertaken for Richmond Valley Council by BMT WBM defined flooding behaviour for the lower Richmond River from Casino to Broadwater including the Wilsons River from Lismore and the lower Bungawalbin Creek. A dynamically linked 1D/2D hydraulic model was developed with the Evans River and floodplain represented as 1D elements. The inclusion of the Evans River was to allow for flows to leave the Richmond River and it was not explicitly part of the mapping study. Therefore the study did not present flood maps of the Evans River.

Climate Change Assessment for the Tuckombil Barrage (2008)

This study was undertaken by BMT WBM for Richmond River County Council to determine the water levels at the Tuckombil Barrage during a standard spring tide, and during the same tide including a 400mm increase to mean sea levels due to climate change. No local rainfall or storm surge was included in the modelling.

Tuckombil Canal Management Structure - Review of Gate Alternative (2007)

GHD prepared a report for Richmond River County Council which reviewed international best practice with regard to gate technologies and assessed two gate options. The gate options were compared on a cost basis with the re-installation of an inflatable dam.

Tuckombil Barrage Flood Affect Assessment (2005)

This study was prepared by WBM Oceanics to present the findings from investigations into the flood affect of different weir heights at the Tuckombil Barrage. The modelling used for this study was the first 2D model of the Mid-Richmond area.

1.4 Structure of this Report

The remainder of this report is structured as follows:

- Section 2 provides an overview of the study area and historical flood risk.
- Section 3 documents the data collection and review process.
- Section 4 describes the development of the models including methodology, key inputs and assumptions.
- Section 5 details the verification of the hydraulic model against historic events.
- Section 6 describes the design event modelling and provides the design mapping output.
- Section 7 lists the key conclusions made from this study.

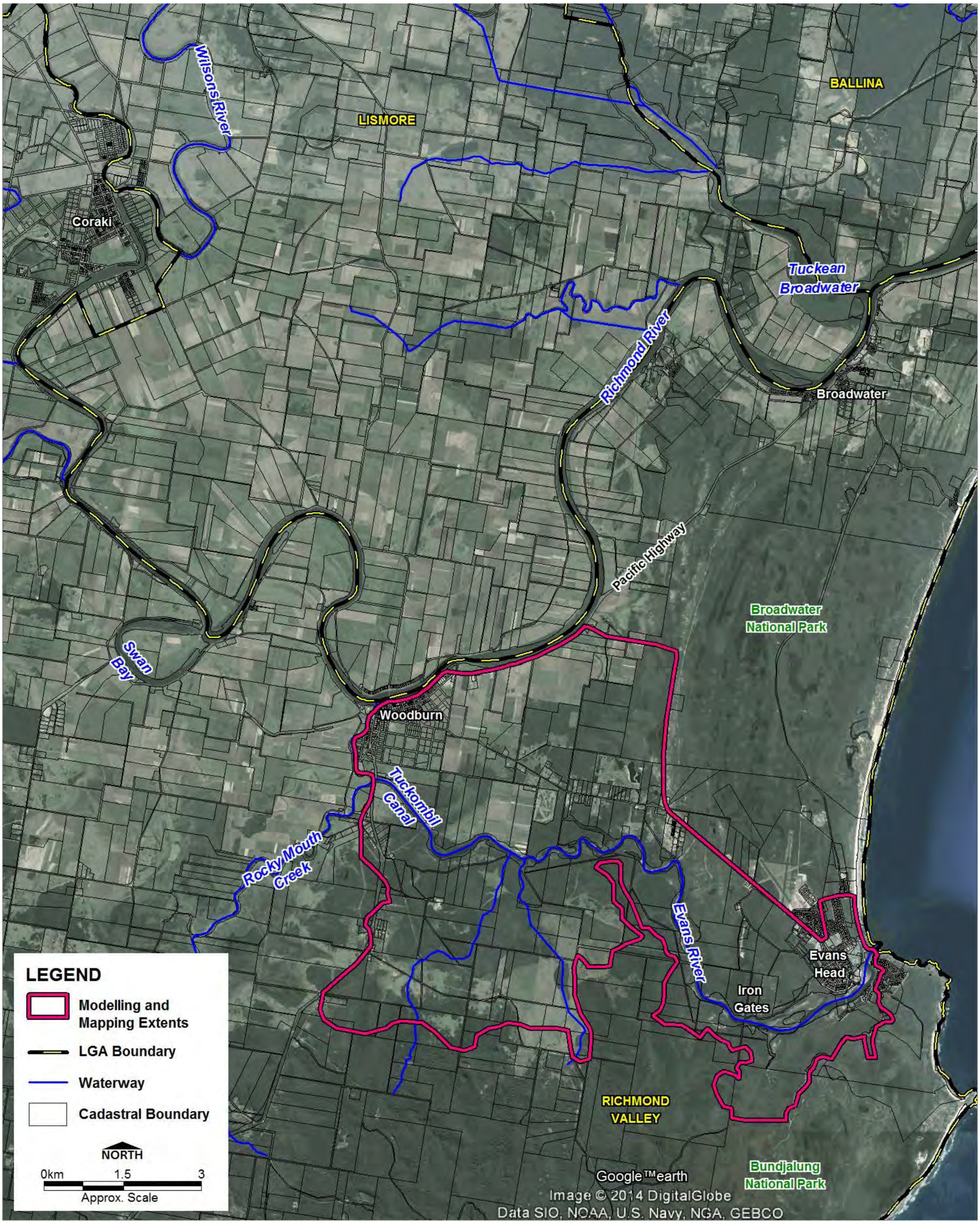

Figure 1-1 Locality Plan – Aerial Photograph

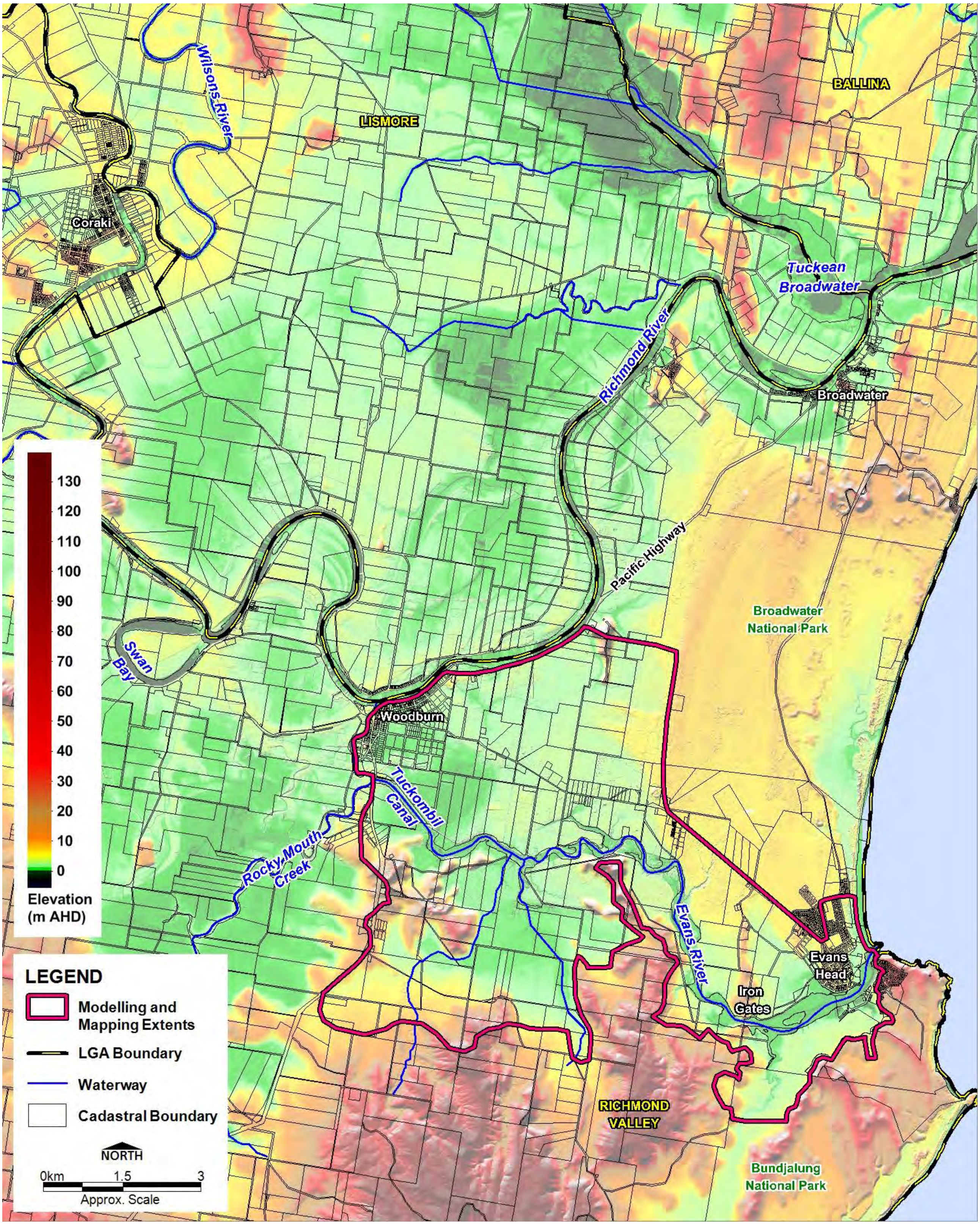

Figure 1-2 Locality Plan – Topography

2 Study Area

2.1 Catchment Description

Located between the towns of Woodburn and Evans Head, the Evans River drains a local catchment of approximately 90km^2. The exact extent of the catchment is difficult to define, since the floodplain in the upper reaches of the Evans River is shared with the Richmond River with no clear catchment divide. During moderate to major flood events, the Evans River receives flows from the Richmond River via defined waterways and overland flow. Refer to Figure 2-1 for study area. The Evans River catchment is entirely within the Richmond Valley local government area.

In 1895, the connectivity between the Richmond River and the Evans River was formalised through construction of the Tuckombil Canal. The canal is 1.5km long, connecting the upstream end of the Evans River to Rocky Mouth Creek, two kilometres upstream of the confluence with the Richmond River at Woodburn. A concrete weir separates Rocky Mouth Creek from the more saline waters of the Tuckombil Canal and Evans River. From the weir (Figure 2-2) to the river mouth at Evans Head (Figure 2-3), the Evans River system is 15km long.

The Tuckombil Canal was excavated for flood mitigation purposes following significant flooding on the Richmond River in the 1890's. Prior to the creation of the canal the Evans River drained a local catchment area and only received flows from the much larger Richmond catchment during major flood events. The canal was deepened and widened in 1965 to its present dimensions. The deepening necessitated the construction of the weir. Since 2001 this barrier has been formed by a concrete weir with crest elevation of 0.94m AHD. Previous manifestations include inflatable fabridams and a steel sheet piling coffer dam.

The Evans River drains the hills in and around Bundjalung National Park, on the southern side of the river. On the northern side, the topography is flatter with the river draining parts of the Broadwater National Park.

The only town within the Evans River catchment is Evans Head, with a population of approximately 3,000, located at the outlet of Evans River into the ocean. As such it is the principal town at risk to flooding from the Evans River and the ocean.

Two bridges cross the Evans River; one is the Pacific Highway crossing at the upstream end of the Tuckombil Canal (Figure 2-2) and the other is the Evans Head, Elm Street Bridge (Figure 2-4)

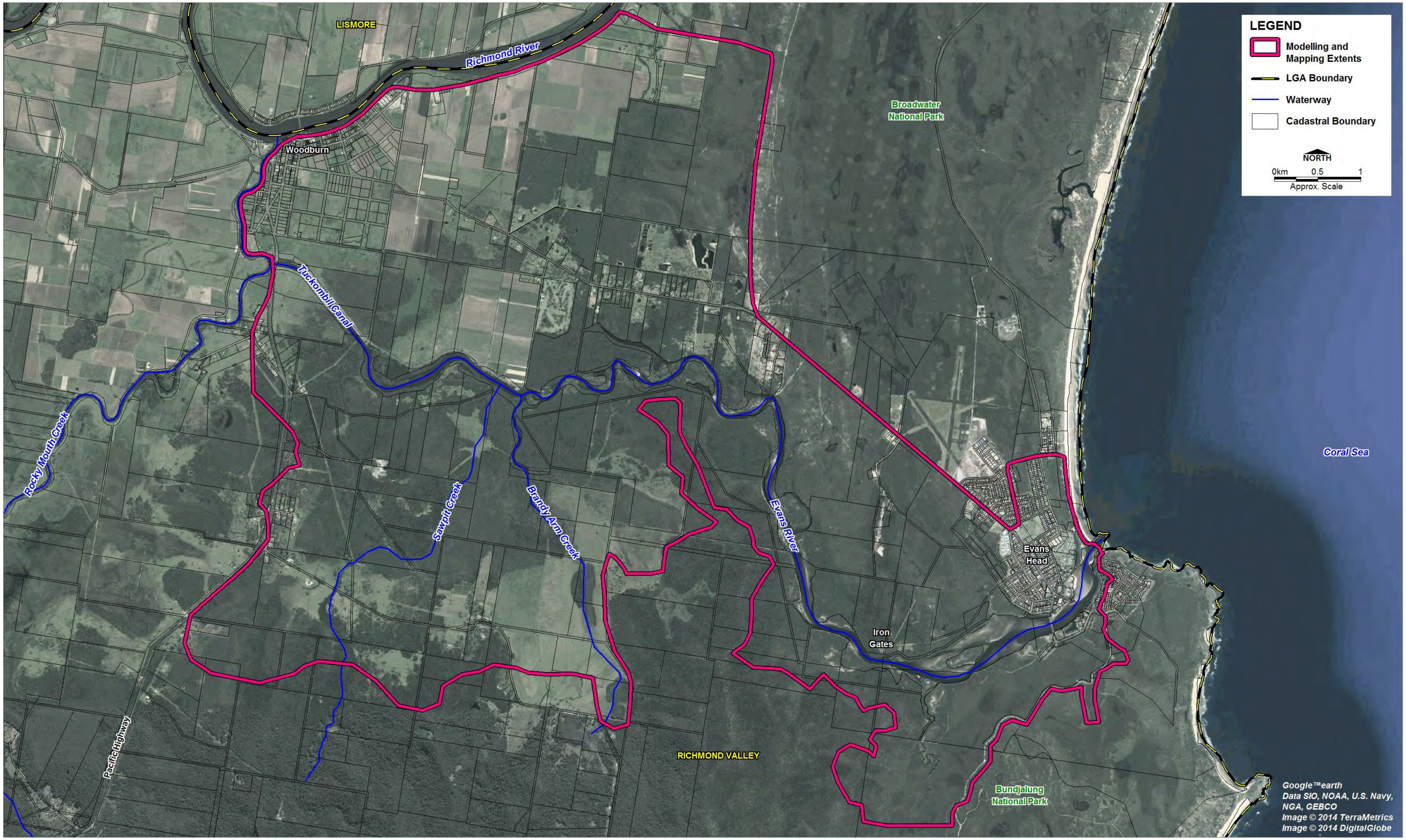

Figure 2-1 Study Area

Figure 2-2 Tuckombil Canal Weir and Pacific Highway Bridge
(Tuckombil Canal in the foreground, Rocky Mouth Creek in the background)

Figure 2-3 Evans River Mouth at Evans Head

Figure 2-4 Elm Street Bridge at Evans Head

2.2 Flood Mechanisms and History

There are three potential sources of flooding along the Evans River:

- Local catchment runoff – high intensity, short duration rainfall has the potential to cause localised flooding in the Evans Head urban area, as well as across agricultural land. This type of flooding is typically of short duration, and will occur as waters drain into the Evans River, rather than flows breaking out from the Evans River.
- Storm surge – due to the close proximity to the ocean, large storm surges caused by tropical cyclones or low pressure systems can result in flooding of the low lying areas.
- Richmond River overflow – as floodwaters in the Richmond River and Rocky Mouth Creek cause overtopping of the Tuckombil Canal weir, flood levels in the Evans River will rise as a result. Overflow from the Richmond River poses the greatest flood risk to most of the Evans River catchment.

Most flood events will involve more than one of these sources of flooding. The relative timing of each source is an important factor dictating the magnitude of the ensuing flood. For example, local catchment runoff will drain from the river before the Richmond River flood, however, should the Richmond River flood occur simultaneously with a high tide or the peak of a storm surge, a large flood could result.

Historically, significant flood events on the Evans River are dominated by large events on the Richmond River overtopping the Tuckombil Canal weir and entering the Evans River. In addition to the flows within the Tuckombil Canal, moderate to major floods in the Richmond River will overtop the banks of the river, inundating the low lying floodplain and subsequently draining to the Evans River. Significant events have occurred in 1954 and 1974. The 1974 flood was noted as being particularly severe as it occurred during high spring tides.

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3 Data Collation and Review

3.1 Aerial Photography

Various sources of aerial photography have been used for coverage of the entire Evans River catchment. All imagery used has been captured between 2007 and present. Aerial photography has been provided by Richmond Valley Council and Richmond River County Council. Where required, Microsoft Bing and Google Earth imagery has also been used.

The available imagery has been used for identification of land use and ground roughness for hydraulic modelling, and for presentation of flood maps.

3.2 Topographic Survey

3.2.1 Aerial Survey

The previous *Richmond River Flood Mapping Study (RRFMS) (BMT WBM, 2010)* used a compilation of aerial survey datasets for generation of a topography mosaic. The RRFMS dataset was assessed for accuracy against recent survey captured across the Mid-Richmond and Evans River areas. The most reliable and accurate datasets were then merged into a single digital elevation model (DEM). The resulting DEM used for the Evans River flood modelling incorporates:

- Photogrammetry captured in 2007 for the RRFMS; and
- LiDAR survey captured in 2010 by the NSW Department of Land and Property Information.

Refer to Figure 3-1 for the DEM of the study area.

3.2.2 Ground Survey

Ground survey across the study area has previously been collected for:

- Mid-Richmond Flood Study (WBM, 1998); and
- Richmond River County Council levee survey (2010).

The survey typically comprises spot heights along hydraulic controls, such as road embankment and levees. Available ground survey is shown in Figure 3-2 Bathymetric Survey

Bathymetric survey of the estuarine extents of the Richmond River and Evans River systems was captured in 2004 as part of the NSW Department of Natural Resources' (DNR) Estuary Management Program. The survey was provided for this project by the NSW Office of Environment and Heritage (OEH). Refer to Figure 3-2 for extents of bathymetric survey.

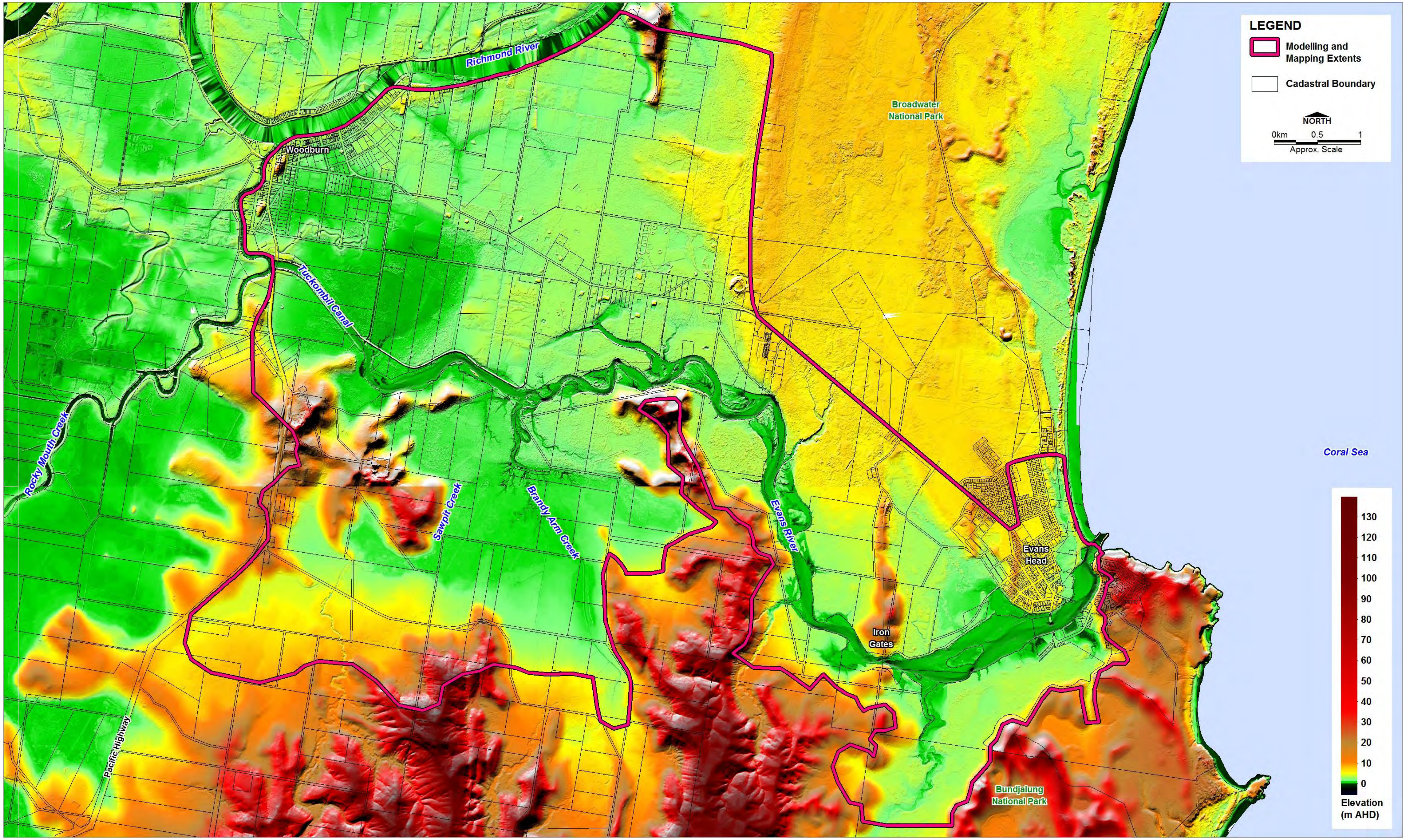

Figure 3-1 Digital Elevation Model

Figure 3-2 Additional Topographic Data

3.3 Historic Flood Levels

There have been numerous floods that have occurred in the area, including:

- February 1954;
- March 1974;
- January 2008; and
- May 2009.

Extensive field data collection occurred during the January 2008 and May 2009 flood events, as part of the *Richmond River Flood Mapping Study (BMT WBM, 2010)*. However no flood levels were recorded in the Evans River catchment.

There are a limited number of historic flood levels available for the 1974 event. These are located in the floodplain of the upper Evans River with none at Evans Head. Refer to Figure 3-3 for the locations.

3.4 Rainfall, Stream Flow and Tidal Data

The following data have been collated for this study:

- Daily, hourly and continuous (5 minute or 6 minute pluviographic) rainfall records were sourced from the Bureau of Meteorology (BoM), NSW Office of Water and Manly Hydraulic Laboratory (MHL) for the wider catchment.
- River level data sourced from MHL for the Irongates and Fishermans Co-op gauges for the May 2009 flood event (see Figure 3-3 for locations). No gauged data was available within the Evans River catchment for the March 1974 event.
- Tidal data sourced from MHL for the May 2009 event. Tidal data for the March 1974 event was used in accordance with the *Mid-Richmond Flood Study (WBM, 1999)*. The tide levels used for that study are based on recordings at Coffs Harbour with an additional 300mm added to account for storm surge.

3.5 Structures

The following key structures have the potential to affect flood behaviour along the Evans River:

- Elm Street Bridge – the Evans Head Bridge links South Evans Head to Evans Head and was constructed in 1961.
- Tuckombil Canal and Weir – the Tuckombil Canal was originally excavated in 1895 between Rocky Mouth Creek and the Evans River. The canal was intended to provide flood relief to the Mid-Richmond area, allowing floodwaters to drain to the ocean via the Evans River, while preventing tidal exchange. The canal was excavated to its current form in 1965, which included a fabridam at the upstream end. This fabridam was replaced in 2001 by a fixed concrete weir with a level of 0.94m AHD.

In addition, there are numerous other smaller levees that divert floodwater within the floodplain.

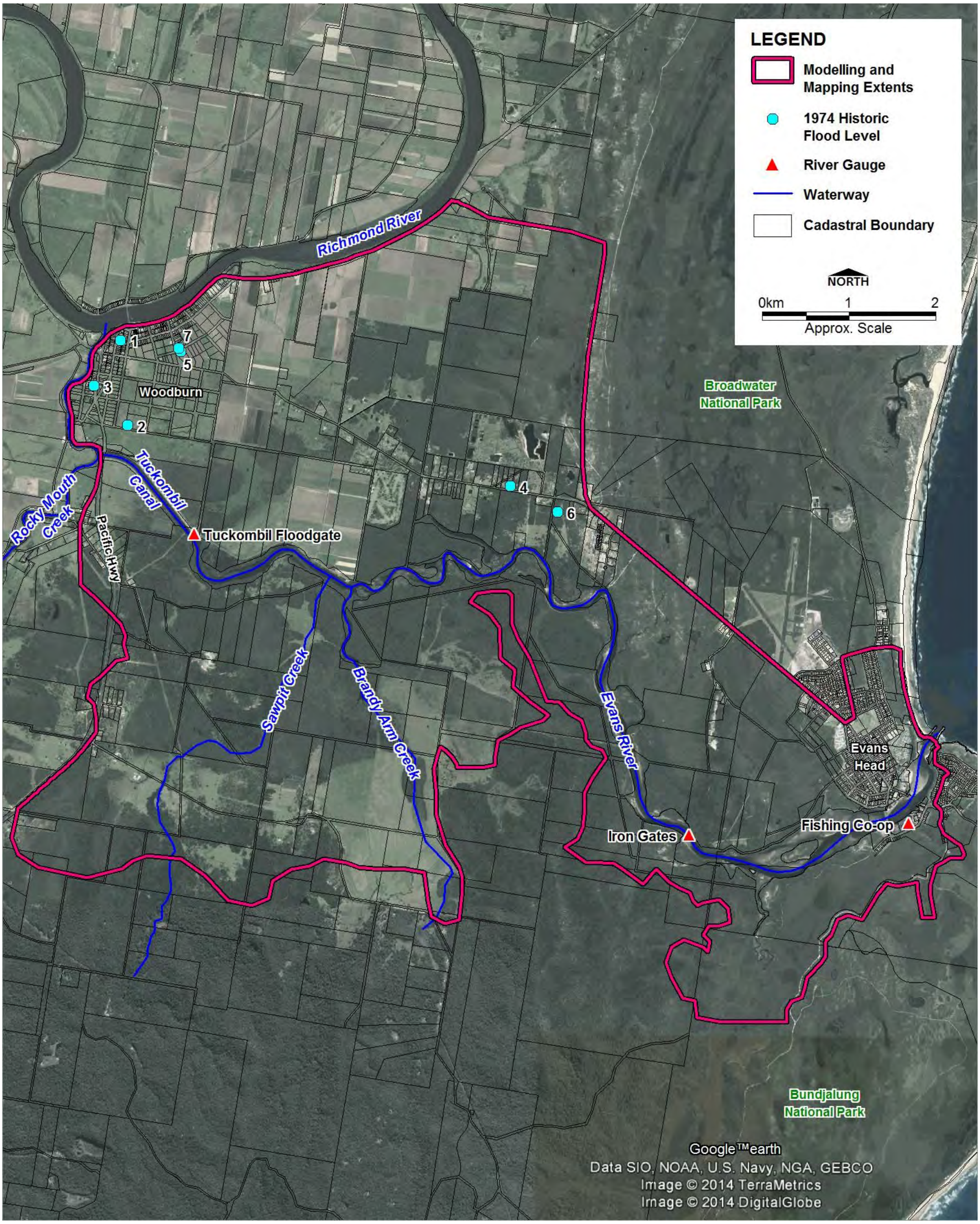

Figure 3-3 Evans River Gauges and Historic Flood Levels

4 Model Development

4.1 Background

Development of a flood model typically involves two key components. Firstly, a hydrologic model is developed to estimate the amount of runoff during a given storm event. Historical or design rainfall are applied to the hydrologic model, which uses algorithms to convert the rainfall to runoff, and route the runoff through the catchment. These runoff-routing models are simplistic representations of the catchment, generally requiring minimal geographical input data.

Secondly, a hydraulic model is developed to simulate the passage of this runoff through the catchment. Inflow hydrographs, estimated using the hydrologic modelling, are applied at the upstream ends of waterways and floodplains. Rainfall over the hydraulic model area is applied directly to the cells of the hydraulic model. Hydraulic models are generally more complex and data intensive.

The development of each model is described in more detail in the following sections.

4.2 Hydrologic Model

The hydrologic models developed during the *Richmond River Flood Mapping Study (BMT WBM, 2010)* covered the entire Richmond and Evans River systems. These models use the WBNM modelling platform. Since publication of the RRFMS, these models have undergone extensive revision. The updated models have been used to feed inflows into the updated Richmond River flood model, which has been used to determine inter-catchment flow from the Richmond River to the Evans River catchment. In total 16 sub-catchments are used to represent the Evans River local catchment area. These sub-catchments, together with surrounding sub-catchments that drain to the Richmond River are shown in Figure 4-1.

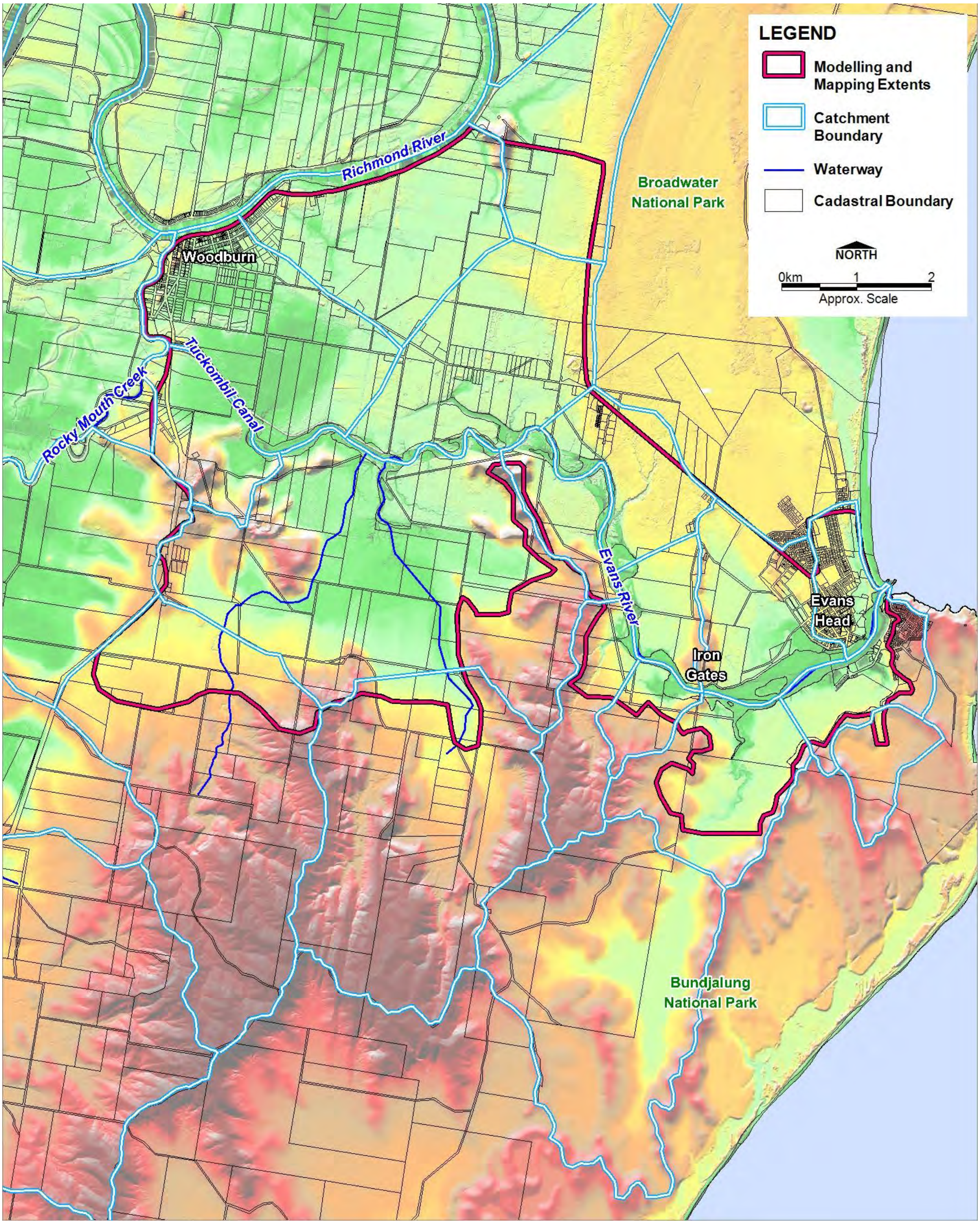

Figure 4-1 Catchment Hydrology

4.3 Hydraulic Model

4.3.1 Previous Models

There are numerous hydraulic models of the area currently available.

The RRFMS study in 2010 represented the most comprehensive hydraulic modelling of the Richmond River to date. It consisted of a 1D/2D dynamically linked TUFLOW model. The model included the Evans River as a 1D/2D linked model downstream to Doonbah, beyond which it was solely a 1D model.

Two studies were since undertaken which made separate modifications to the RRFMS model in the vicinity of Evans River:

- In 2012, the original RRFMS model was enhanced as part of the Iron Gates flood impact assessment. This study increased the 1D/2D model extent to the mouth of the Evans River. This included updates to the terrain within the model extension, and mapped the current land uses.
- In 2013, the original RRFMS was updated with the 2010 LiDAR and levee survey as part of the Roads and Maritime Services study for the Pacific Highway Upgrade. The model extents were not increased and the majority of the Evans River remained as a 1D only section of the model.

4.3.2 Evans River Model

As part of this Evans River Flood Study a new model was created of the Evans River. The model extends from the Tuckombil Canal down to the ocean at Evans Head. TUFLOW software was used and the relatively fine scale 10m grid resolution of the model enabled a purely 2D model to be developed.

The model relies upon extraction of water level data from the RRFMS flood model which are then applied as inflows to the Tuckombil Canal and along the adjoining floodplain.

Figure 4-2 shows the extent of the Evans River Model developed for this study.

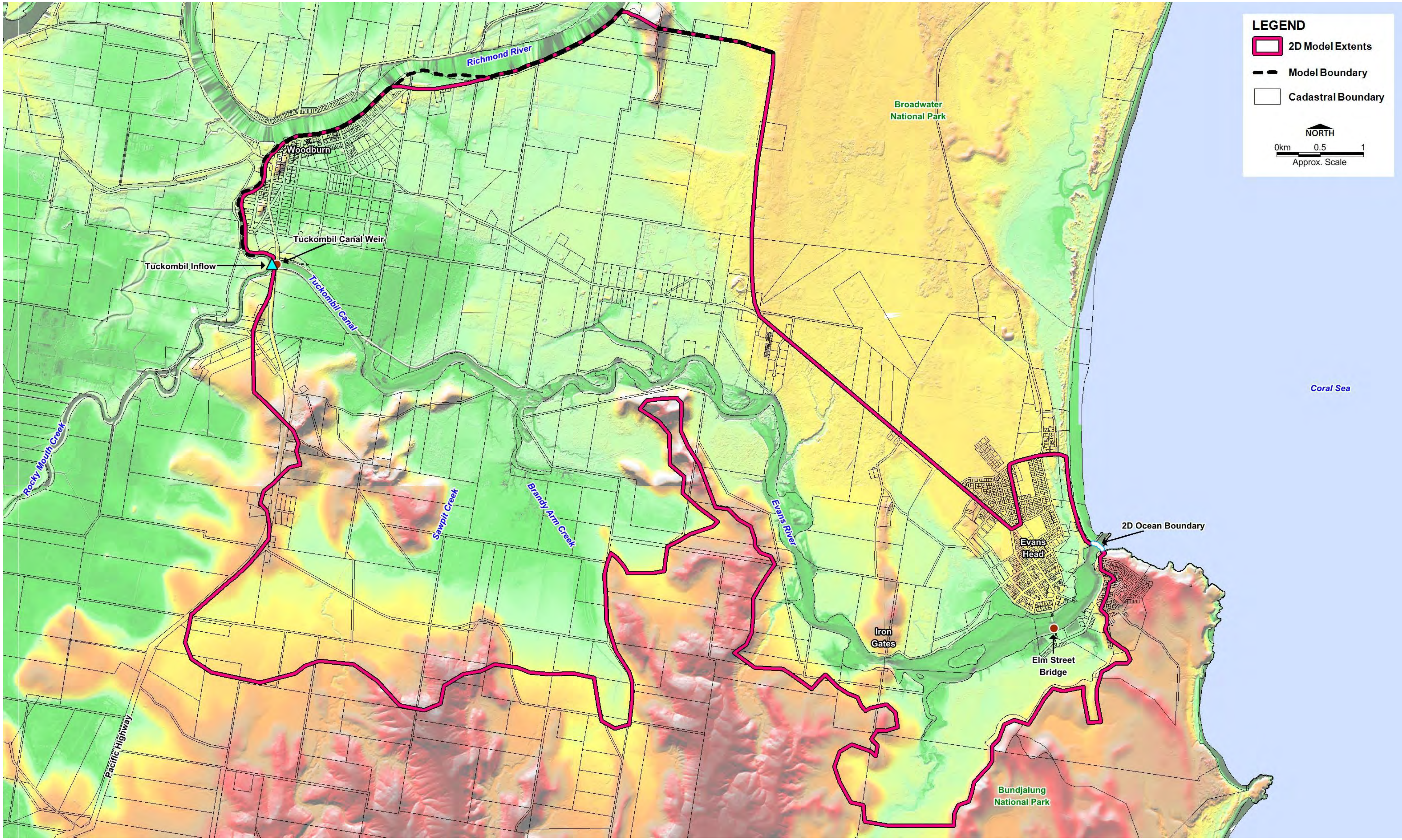

Figure 4-2 Hydraulic Model Layout

4.3.2.1 Model Geometry

The base topography of the model is derived from 1m horizontal resolution 2010 LiDAR data which represents the latest aerial survey data available. The base data has been supplemented with bathymetric survey data of Evans River collected in 2004. The grid resolution of the model is 10m.

Additional modifications to represent raised levees, road embankments and minor drainage channels have been included as follows:

- 2013 ground survey data of the northern bank of the Tuckombil Canal extending from the Pacific Highway to 3.5km downstream and then inland for 1.2km alongside the Golf Club.
- Ground survey data of levees and roads, undertaken by Michel Surveys for RRCC in 1998/1999.
- Levee crest elevations along the southern bank of the Richmond River extending from Rocky Mouth Creek to the north eastern extent of the Evans River model. These elevations have been extracted from the 2010 LiDAR.
- Levee crest elevations along both banks of the Evans River extracted from the 2010 LiDAR.
- Minor drainage channels in the area surrounding Woodburn extracted from the 2010 LiDAR.

Locations of levees and drainage features are included in Figure 3-2. Where levee datasets overlap then preference has been given to ground survey data.

4.3.2.2 Modelled Structures

Two major structures located within the Evans River model have been included as follows:

- Elm Street Bridge at Evans Head (Figure 2-4) – No survey elevations were available for the 130m span road bridge and adjacent footbridge. However, bridge obvert elevations have been estimated to range from 3.5m AHD near the bank to 4m AHD at the centre.
- The Tuckombil Canal Weir (Figure 2-2) has been included in the model with a fixed elevation of 0.94mAHD representing the current weir height.

4.3.2.3 Landuse Mapping

Ground surface roughness can have a significant influence on the flow of water. Ground roughness is represented in the model by assigning Manning’s ‘n’ values for different land uses. Land use was determined from aerial photography along with on-site ground truthing.

Values of Manning’s ‘n’ for different land uses were selected based on industry accepted values and are shown in Table 4-1.

Table 4-1 Manning's 'n' Roughness Values

Ground Cover	Manning's 'n' Value
Pasture	0.05
Cultivated fields	0.06
Sugar Cane	0.15
Maintained Grass	0.035
Sparse Vegetation, Top of Banks	0.09
Medium Density / In-Creek Vegetation	0.10
Dense Vegetation	0.12
Sandy Areas, Low Vegetation	0.07
Sandy River Bed	0.025
River Bed	0.040
Rough River Bed	0.06
Stony River Bed	0.07
Roads	0.025
Urban and Commercial Blocks	1.00
Sparse Urban Blocks	0.20

4.3.2.4 Model Boundaries

The upstream boundary to the Evans River model extends from alongside eastern bank of Rocky Mouth Creek and the southern bank of the Richmond River (see Figure 4-2). The boundary has been schematised in the model as a time varying water level boundary. Time series data of water levels were extracted from the RRFMS model and applied to the Evans River model.

A study of elevated ocean water levels (i.e. from cyclones and east-coast tropical lows) was carried out for the Richmond River entrance (Lawson & Treloar, 1994). The study considered the probability of elevated ocean water levels due to low pressure systems and wave forces.

Extended investigations of that study in 1995 produced a set of water level hydrographs over the duration of a flood event for various probabilities of recurrence. These hydrographs were used in the hydraulic model to simulate the effects on flooding in the Richmond River floodplain of elevated and varying ocean water levels. The storm tide peak was timed to coincide with the local rainfall peak which is approximately three days before the Richmond River flood peak at Broadwater.

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5 Model Calibration and Verification

The Richmond River has been subject to a number of flood events. Floodwater originating from the Richmond River is the dominant cause of flooding to the Evans River catchment.

The Richmond River flood model developed by BMT WBM for RRCC was calibrated as part of the original study to the May 2009 flood event with further verification undertaken for the March 1974 January 2008, and February 1954 events. It is beyond the scope of this study to revisit the calibration of the Richmond River model. However, the Evans River model, which has been developed for this study, requires additional validation to ensure confidence in the performance of the model.

Two verification events have been run through the Evans River model:

- March 1974; and
- May 2009.

The 1974 event was selected as this was particularly severe in coastal regions due to it occurring during a high spring tide cycle. Historic flood levels were also available in the upper Evans River catchment. The 2009 event was selected due to the availability of gauged river levels to aid comparison.

5.1 March 1974 Flood

5.1.1 Event Description

The March 1974 event occurred due to Tropical Cyclone Zoe, which crossed the coast at Coolangatta. Two main bursts of rainfall occurred across the Richmond Valley during the 9/10 and 12/13 March. The main concentration of rain fell across the Wilsons River, with totals for the six day period commencing 9 March exceeding 950mm along the Tweed-Wilsons catchment boundary. Heavy rainfall occurred along the eastern part of the Richmond River catchment, with Woodburn and Broadwater receiving over 750mm during the same six day period.

5.1.2 Model Setup

Inflows entering the Evans River model from the Richmond River were extracted from the Richmond model for the March 1974 event. Outputs from the Richmond River hydrology models covering the Evans River catchment were applied as local inflows to the Evans River model. Rainfall applied in the hydrology models was derived from an analysis of 39 daily and pluviograph stations across the Richmond River catchment.

The original fabridam on the Tuckombil Canal was in place during the 1974 event but has since been replaced by a concrete weir. To replicate the behaviour of the March 1974 event, the weir was removed from the Evans River hydraulic model to represent the deflated fabridam.

5.1.3 Verification Results

Table 5-1 presents the results of the 1974 verification. Locations of historic flood levels are shown in Figure 3-3.

Table 5-1 March 1974 Verification Results

ID	Recorded Flood Level (mAHD)	Modelled Flood Level (mAHD)	Difference (m)
1	4.16	4.11	-0.05
2	4.3	4.13	-0.17
3	4.08	4.19	0.11
4	3.75	3.96	0.21
5	4.06	4.10	0.04
6	3.77	3.88	0.11
7	4.42	4.10	-0.32

From Table 5-1 it can be seen that the model provides a reasonable fit to recorded flood levels.

No gauges of recorded river levels were available for comparison with the model output.

5.2 May 2009 Flood

5.2.1 Event Description

Between 20 and 22 May 2009, heavy rainfall fell across the Richmond River catchment as a result of an east coast low pressure system moving southwards from South East Queensland. The most intense rainfall occurred across the Wilsons River catchment, with a band of less intense rainfall extending southwest across the Bungawalbin Creek catchment.

5.2.2 Model Setup

The recorded water level hydrograph at Tuckombil Bridge was used to generate inflows to the Evans River model for the May 2009 event. Outputs from the Richmond River hydrology models covering the Evans River catchment were applied as local inflows to the Evans River model. Rainfall applied in the hydrology models was derived from an analysis of 61 daily and pluviograph stations across the Richmond River catchment.

No catchment specific changes were made to the hydraulic model for the May 2009 event. The Tuckombil weir was left at its current elevation of 0.94mAHD.

5.2.3 Verification Results

Time series flood level information was available for two gauges during the May 2009 event; Iron Gates and the Fishermans Co-op. Gauge locations are shown in Figure 3-3. Recorded flood levels are plotted against modelled flood levels for the Iron Gates and Fishermans Co-op gauges in Figure 5-1 and Figure 5-2 respectively.

It can be seen that the model performs well with respect to timing and provides a good match to peak flood levels with only minor overestimations. These peak levels are driven by the tide. However it is also evident that the model is overestimating the non-tidal component of the flood levels. This is apparent from the model not capturing the lower portion of each tidal cycle. This is caused by an overstatement of flow entering the catchment from upstream. Local inflows from the Evans River catchment will only play a minor role so it is likely that the higher than expected flows are entering the catchment from the Richmond River.

BMT WBMs experience of modelling in the Richmond River suggests that considerable uncertainty is associated with flows from the Bungawalbin catchment. It was found that a significantly improved calibration could be achieved using the recorded water level hydrograph for the 2009 event at Tuckombil Highway gauge as an upstream boundary to the Evans River model. However as these data have not been subject to quality assurance checking by Manly Hydraulics Lab, they have not been made available for use in the study.

As the Evans River model performs well in determining peak levels then it is considered suitable for the purposes of this assessment which is with regard to deriving flood planning levels. However it is recommended that the verification of the Evans River model is revisited if any significant updates occur to the Richmond River model.

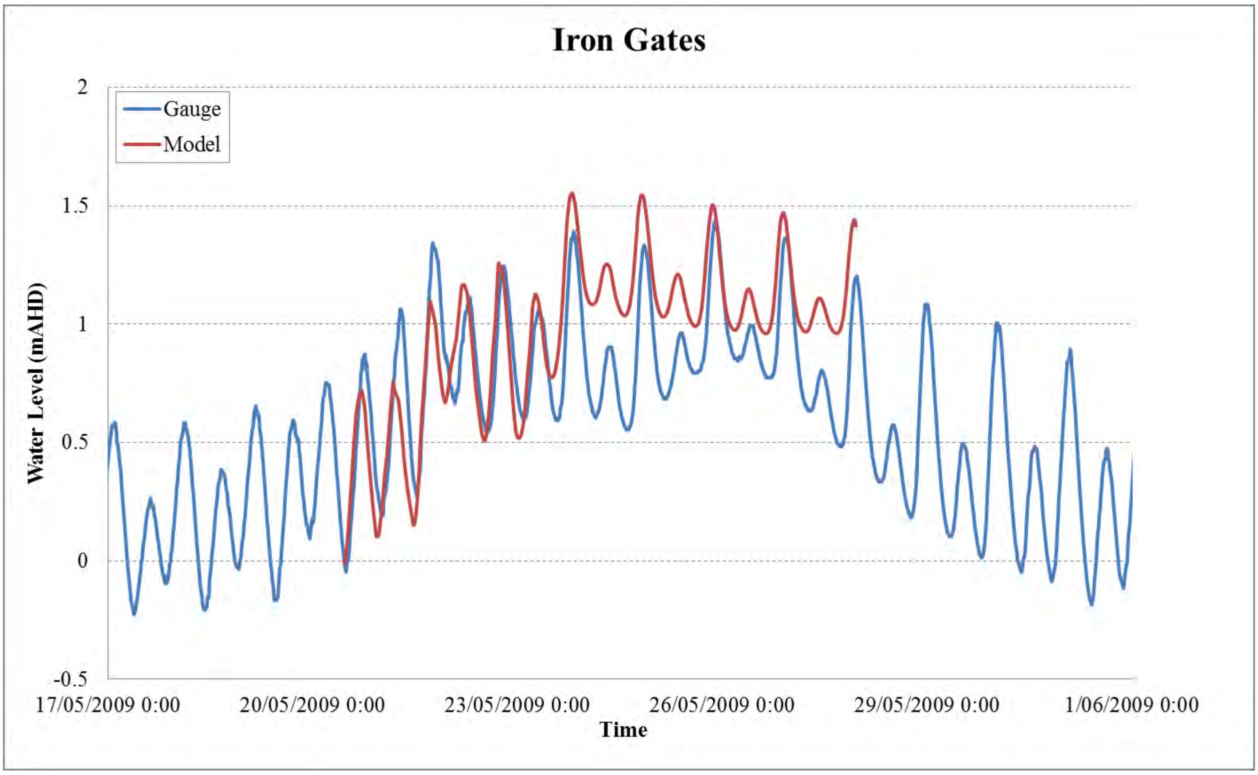

Figure 5-1 May 2009 Recorded vs Modelled Flood Levels (Irongates)

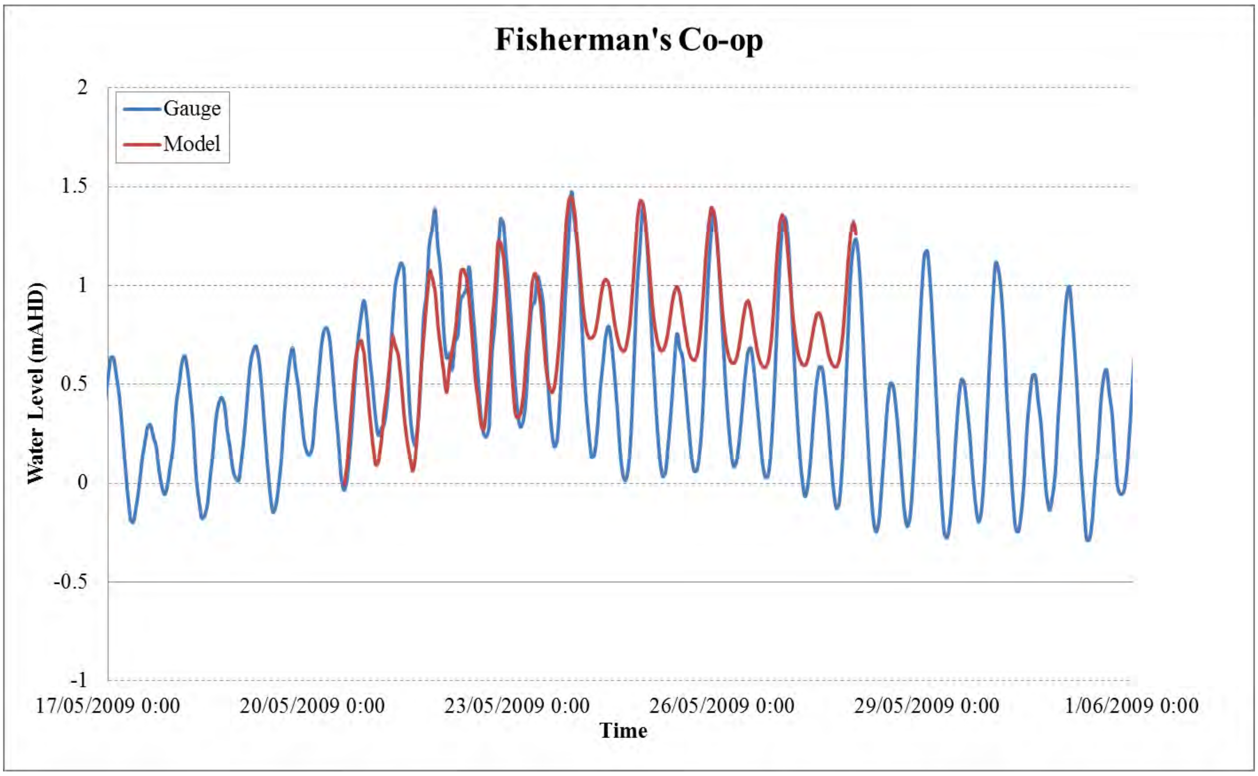

Figure 5-2 May 2009 Recorded vs Modelled Flood Levels (Fishermans Co-op)

6 Design Event Modelling

6.1 Introduction

Design floods are hypothetical floods used for planning and floodplain management purposes. They are based on having a probability of occurrence specified either as:

- Average Recurrence Interval (ARI) expressed in years; or
- Annual Exceedance Probability (AEP) expressed as a percentage.

With the imminent release of the revised Australian Rainfall and Runoff guideline, the industry is standardising and favouring the AEP terminology. However for this study, the ARI terminology has been used for consistency with previous studies in the Richmond River area and familiarity of terminology amongst stakeholders. A definition of ARI and the AEP equivalents are listed in Table 6-1. The 20, 50, 100, 500 year ARI events and the Probable Maximum Flood have been assessed in this study.

Table 6-1 Terminology Used for Design Floods

Category	ARI	AEP[1]	Description
Small Frequent Floods	5 years	20%	A hypothetical flood or combination of floods which is likely to have a 20% chance of occurring in any one year or is likely occur once every 5 years on average.
Medium to Large Floods	20 years	5%	A hypothetical flood or combination of floods which is likely to have a 5% chance of occurring in any one year or is likely occur once every 20 years on average.
	50 years	2%	A hypothetical flood or combination of floods which is likely to have a 2% chance of occurring in any one year or is likely occur once every 50 years on average.
	100 years	1%	A hypothetical flood or combination of floods which is likely to have a 1% chance of occurring in any one year or is likely occur once every 100 years on average.
Rare to Extreme Floods	500 years	0.2%	A hypothetical flood or combination of floods which is likely to have a 0.2% chance of occurring in any one year or is likely occur once every 500 years on average.
	Probable Maximum Flood		A hypothetical flood or combination of floods which represent a theoretical 'worst case' scenario. It is only used for special purposes where a high factor of safety is recommended, or in consideration of floodplain planning (e.g. evacuation and isolation of communities).

[1] The AEPs listed are approximations of the corresponding ARI for ease of reference. For example, a 100 year ARI = 1% AEP, however a 5 year ARI = 18.13% AEP.

6.2 Sources of Flooding

Flooding within the Evans River catchment can originate from three major sources:

- Richmond River flood: spillage of Richmond River flows into the Evans River catchment via the Tuckombil Canal and/or overtopping of the Richmond River and Rocky Mouth Creek embankments;
- Local catchment flood: localised rainfall swelling local creeks and floodplains such as Sawpit Creek, Brandy Arm Creek and local drainage channels within Evans Head; and
- Ocean storm surge: elevated ocean levels caused by low depressions (barometric setup), strong onshore winds (wind setup) and storm wave conditions (wave setup). The peak ocean elevated levels were determined to be 1.6, 1.8 and 2.0 for the 5, 20 and 100 year ARI events respectively.

The design flood modelling undertaken for this study accounts for all three sources of flooding.

6.3 Design Event Hydrology

6.3.1 Design Rainfall

Intensity-Frequency-Duration (IFD) relationships are used to determine the average rainfall intensity for a given storm duration and average recurrence interval. The procedure outlined in Australian Rainfall and Runoff (AR&R) (IEAust, 1987) for calculating an IFD relationship for a point location involves interrogation of point rainfall parameters from six isopleth maps. The six values are supplemented by three geographical parameters. Average rainfall intensity can then be calculated for storm durations ranging from 5 minutes to 72 hours, and for ARIs of 1, 2, 5, 10, 20, 50 and 100 years.

Since IFD parameters relate to a point location, application to a large catchment has its limitations. The preferred approach is to assess a series of IFD parameters, each representing a different part of the catchment. Use of GIS mapping has enabled the parameters to be quickly inspected from digital isopleth maps. Hence, deriving a series of IFD parameters is a relatively quick procedure. The following points outline the approach that has been adopted within the *Richmond River Flood Mapping Study (BMT WBM, 2010)* and subsequently adopted for use with this study:

(1) The Richmond River catchment has been sub-divided into 26 regions, the boundaries of which align with the hydrological model sub-catchment boundaries. The regions generally take consideration of known areas of varying intensity rainfall and topographical features. For example, the steep sub-catchments of the Wilsons River have been assigned a different region than the lower floodplains around Ballina.

(2) IFD parameters were derived for each of the 26 regions as follows:

    (a) Maximum parameter within region;

    (b) Average parameter across region; and

    (c) Parameters at centroid of region.

(3) The resulting sets of IFD parameters were compared for specific locations against those specified in the *Northern Rivers Local Government Handbook of Stormwater Drainage Design* (2006). In general, the IFD parameters calculated using approaches (b) and (c), were lower than the values specified in the handbook. The parameters calculated using approach (a) were higher or consistent with the handbook values. This translates to higher than or consistent rainfall intensities to those used throughout the region for stormwater infrastructure design. Therefore, these higher IFD parameters were adopted for use.

IFD parameters for the Alstonville region have been replaced by the revised parameters issued by the BoM during the *Ballina Floodplain Management Study* (WBM, 1997). The reason for the revision was to account for the occurrence of several storm events with greater than 100 year ARI rainfall intensity since issue of AR&R in 1987. The revised set of parameters results in higher rainfall intensity than otherwise calculated.

For the Mid Richmond River the 72 hour duration resulted in the greatest flows. As the Richmond River floods also dominate the Evans River catchment then the 72 hour duration event also resulted in the greater flows on the Evans River.

6.3.2 PMP Estimation

The probable maximum precipitation (PMP) is defined as '*the greatest depth of precipitation for a given duration meteorologically possible for a given storm area at a particular location at a particular time of year'* (WMO, 1986). The PMP is used to estimate the probable maximum flood (PMF), representing an extreme flood that can be expected to occur on average once every 10,000 to 1,000,000 years, depending on the catchment.

The two methods recommended for calculation of the PMP along the East Coast of Australia are:

- Generalised Short Duration Method (GSDM); and
- Generalised Tropical Storm Method Revised (GTSMR).

As the name implies, the GSDM is used for short duration events on catchments up to 1,000km^2. More applicable to the 7,000km^2 Richmond River catchment is the GTSMR, which is recommended for event durations up to 120 hours.

Presented in Table 6-2, are the total PMP rainfall depths for the Richmond River. Also shown in Table 6-2 are the rainfall depths for the 20, 50, 100 and 500 year ARI events for comparison. The depths shown have not been spatially factored; therefore, represent an average depth across the catchment.

Table 6-2 Comparison of Design Rainfall Depths

Event Duration	Richmond River Average Design Rainfall Depth* (mm)				
	20 year	50 year	100 year	500 year	PMP
24 hour	240	286	322	-	840
36 hour	284	339	382	-	990
48 hour	318	381	430	548	1,120
72 hour	366	440	498	651	1,360
96 hour	-	-	-	-	1,550
120 hour	-	-	-	-	1,630

* depths presented are un-factored, based on catchment average

6.3.3 Design Rainfall Losses

Values applied for initial and continuing losses are 20mm and 2.0mm/hr respectively. These values are in accordance with AR&R and have been used for all design events.

6.3.4 Design Ocean Boundary

As discussed in Section 4.3.2.4 design ocean boundaries have been applied so that the peak coincides with the peak of the design rainfall event. Figure 6-1 shows the 100 year ARI downstream boundary applied in the model where a peak ocean level of 2.0m AHD is used.

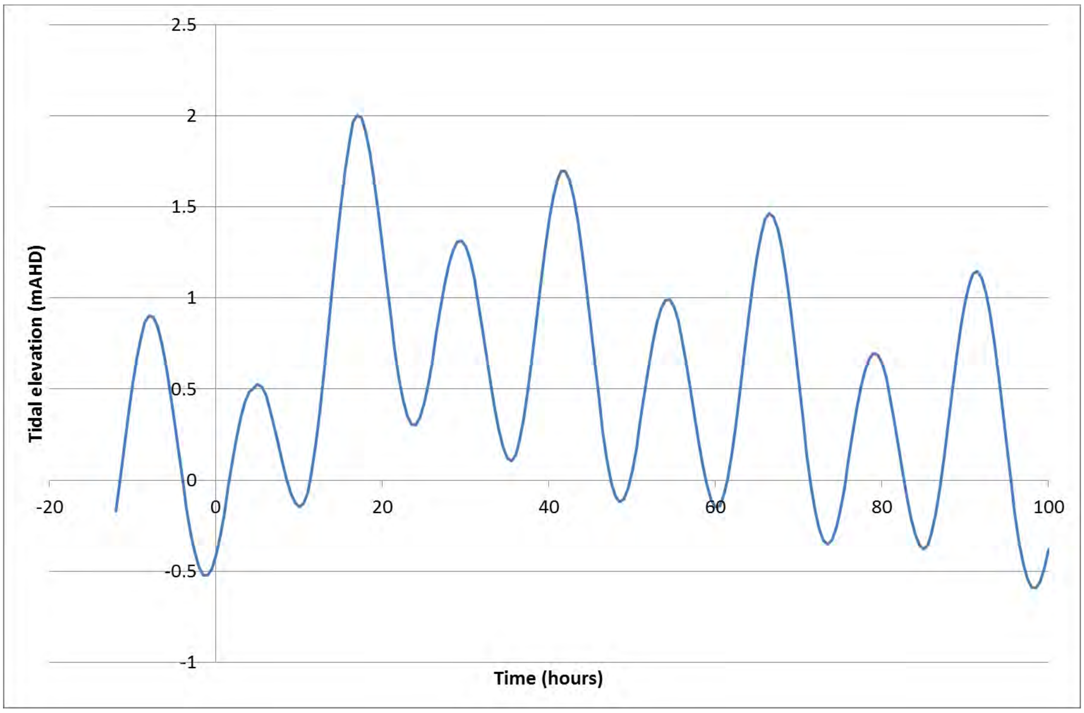

Figure 6-1 100 year ARI Downstream Boundary

6.4 Design Flood Mapping

The interpretation of maps within this report should be done with an appreciation of any limitations with their accuracy. Whilst the points below highlight these limitations, it is important to note that the results presented provide a current prediction of design flood behaviour:

- Recognition that no two floods behave in exactly the same manner;
- Design floods are a 'best estimate' of an average flood for their probability of occurrence; and
- Approximations and assumptions are made in the modelling and mapping process as discussed throughout this report.

6.4.1 100 Year ARI Design Flood

Figure 6-2 to Figure 6-5 present maps showing peak 100 year ARI flood levels, depths, velocities and hazard respectively. Figure 6-6 presents a map of peak 100 year ARI flood levels focussed on the Evans Head area. Figure 6-6 also includes the coastal hazard beach regression planning line for the year 2100 as derived by Hydrosphere Consulting.

It can be seen from the Figures that flooding is extensive across the upper part of the Evans River catchment with the extent narrowing towards the natural constriction in the terrain at Iron Gates. Flood elevations in this upper floodplain typically range between 4.5 and 5.7m AHD. At Iron Gates the flood elevation decreases to approximately 2.5m AHD.

The 100 year peak velocity map shows the main locations where floodwater spills into the upper Evans river floodplain from the Richmond River. As the Richmond River nears its peak level these inflow locations largely merge into a continuous inflow.

The natural constriction at Iron Gates limits the width of the flood extent to around 90m and this in turn creates some of the highest flood velocities within the catchment at around 4m/s. Additional information on floodplain constrictions is provided in Section 6.6.2.

At Evans Head the flood elevations along the river typically range between 2.0m AHD and 2.3m AHD. The majority of the town is located at elevations sufficient to be above the 100 year ARI flood levels. Low lying parts of the town are affected and these are:

- Bundjalung Road and the harbour at South Evans Head; and
- The Silver Sands Holiday Park within Evans Head.

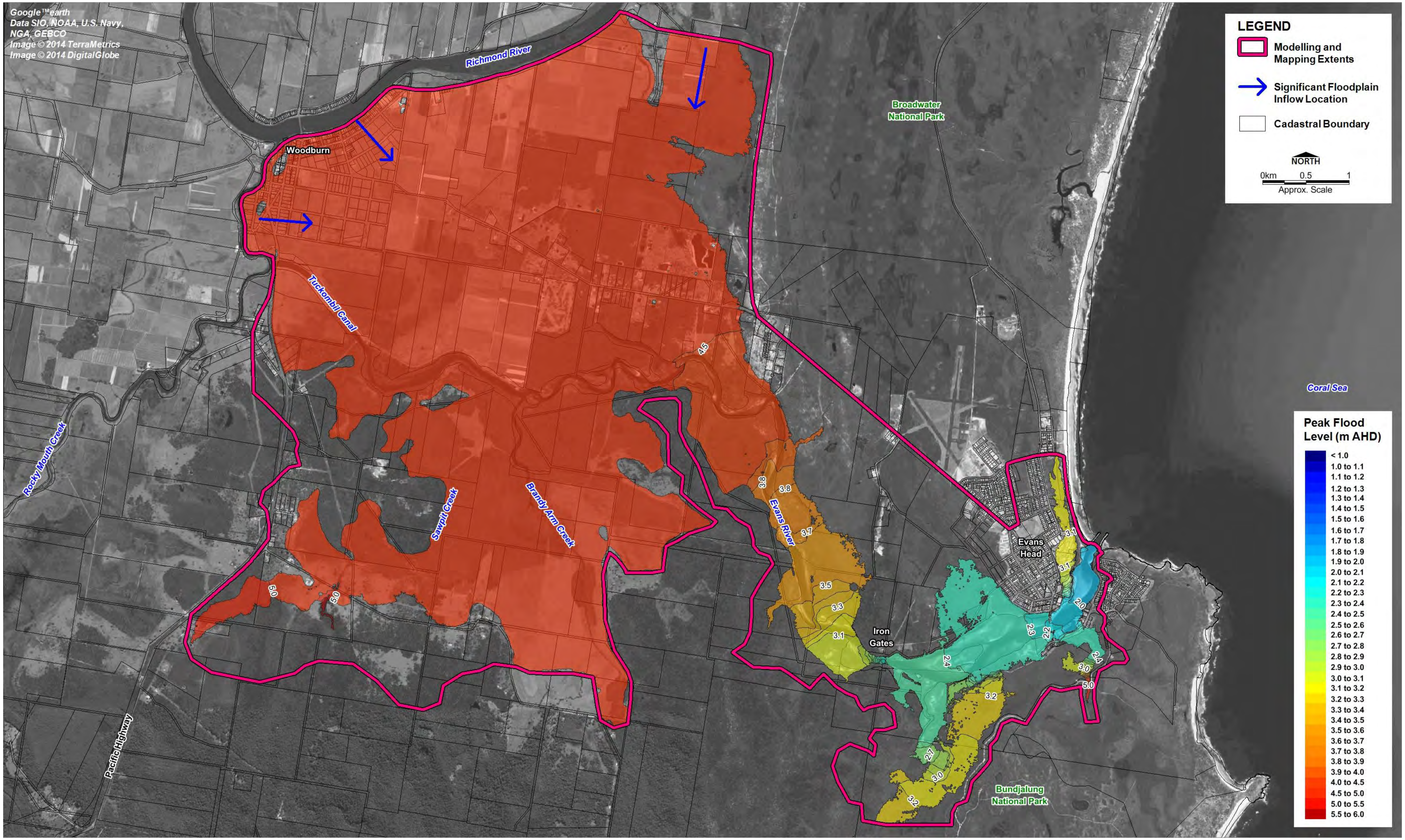

Figure 6-2 100 year ARI Flood Levels

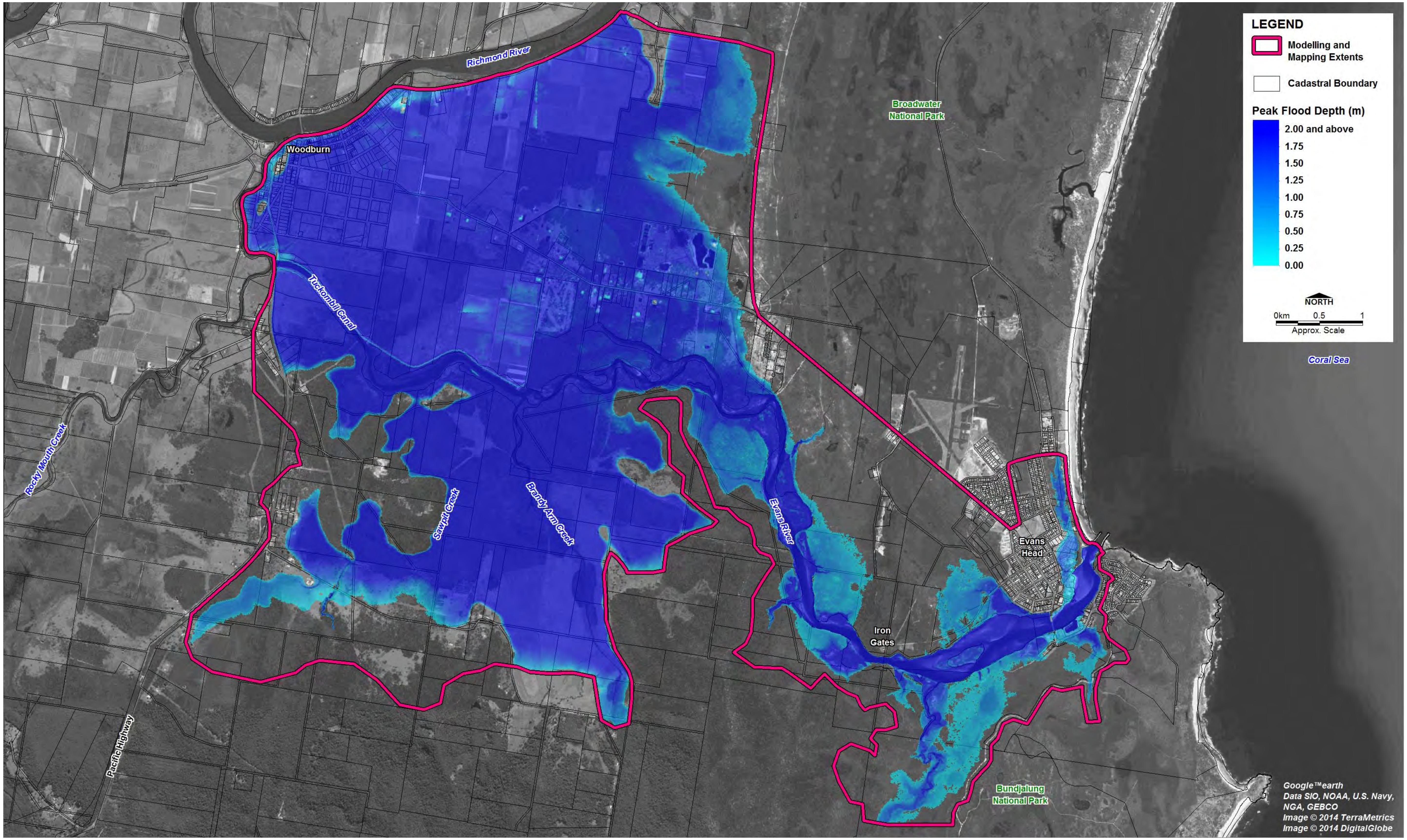

Figure 6-3 100 year ARI Flood Depth

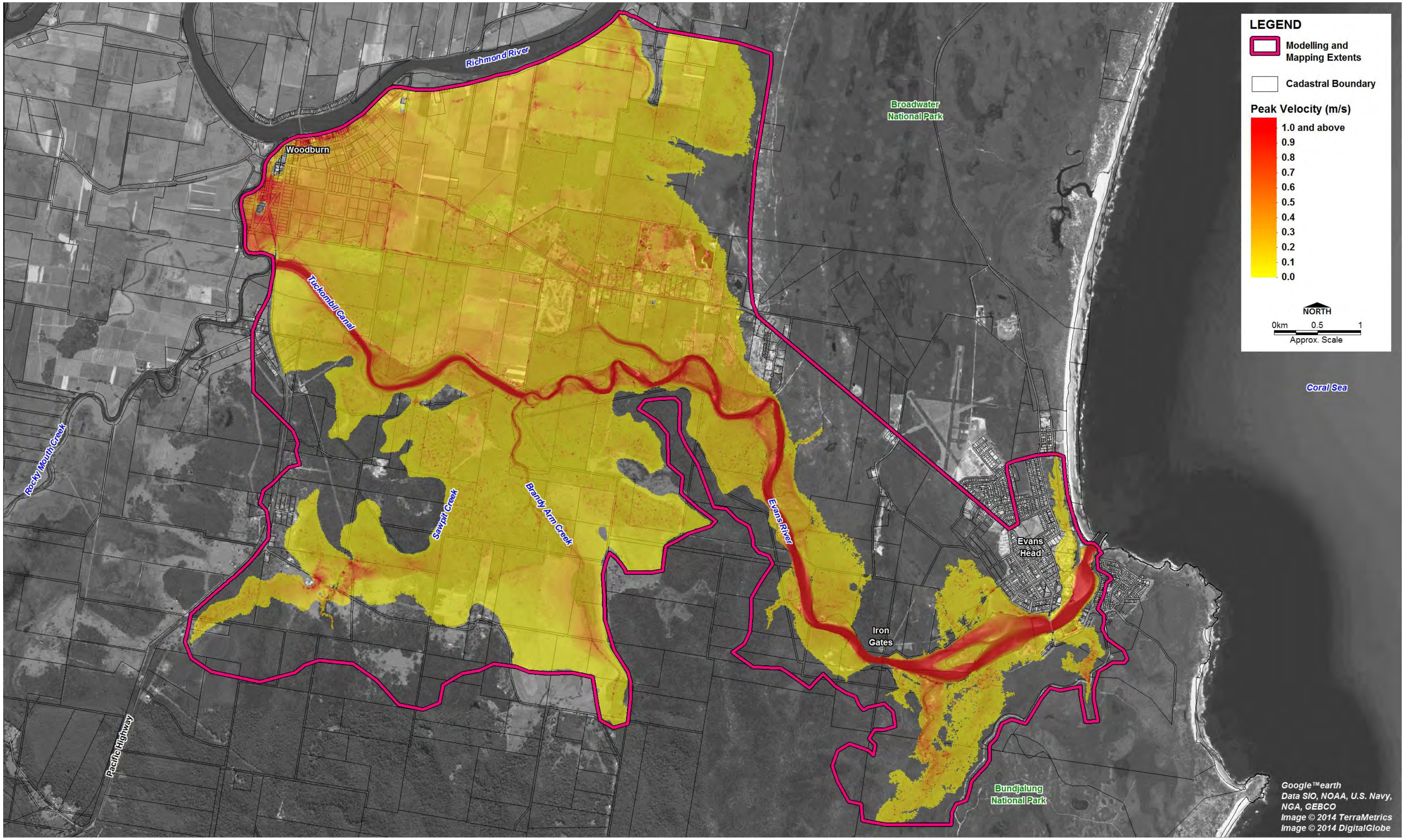

Figure 6-4 100 year Flood Velocity

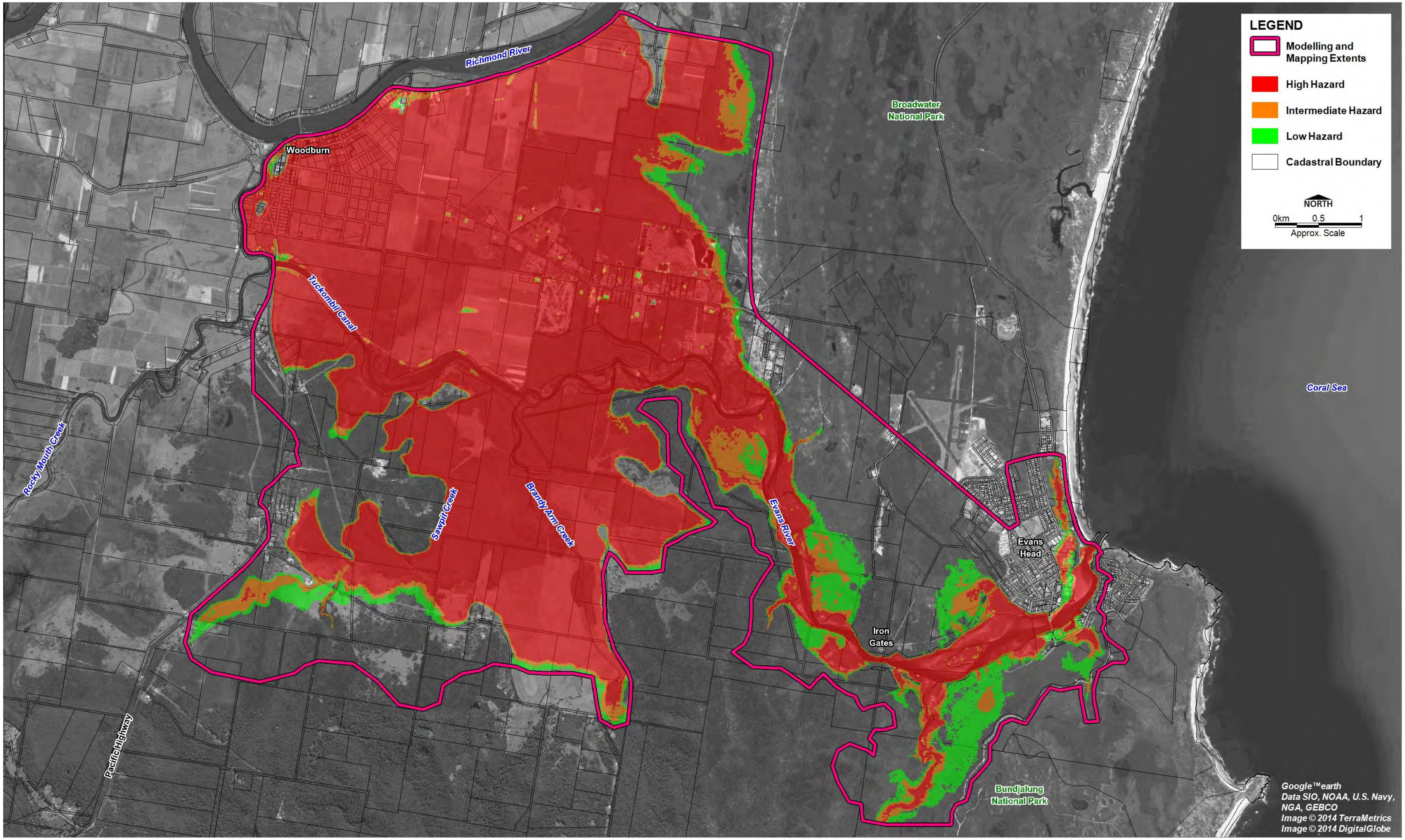

Figure 6-5 100 year ARI Flood Hazard

BMT WBM

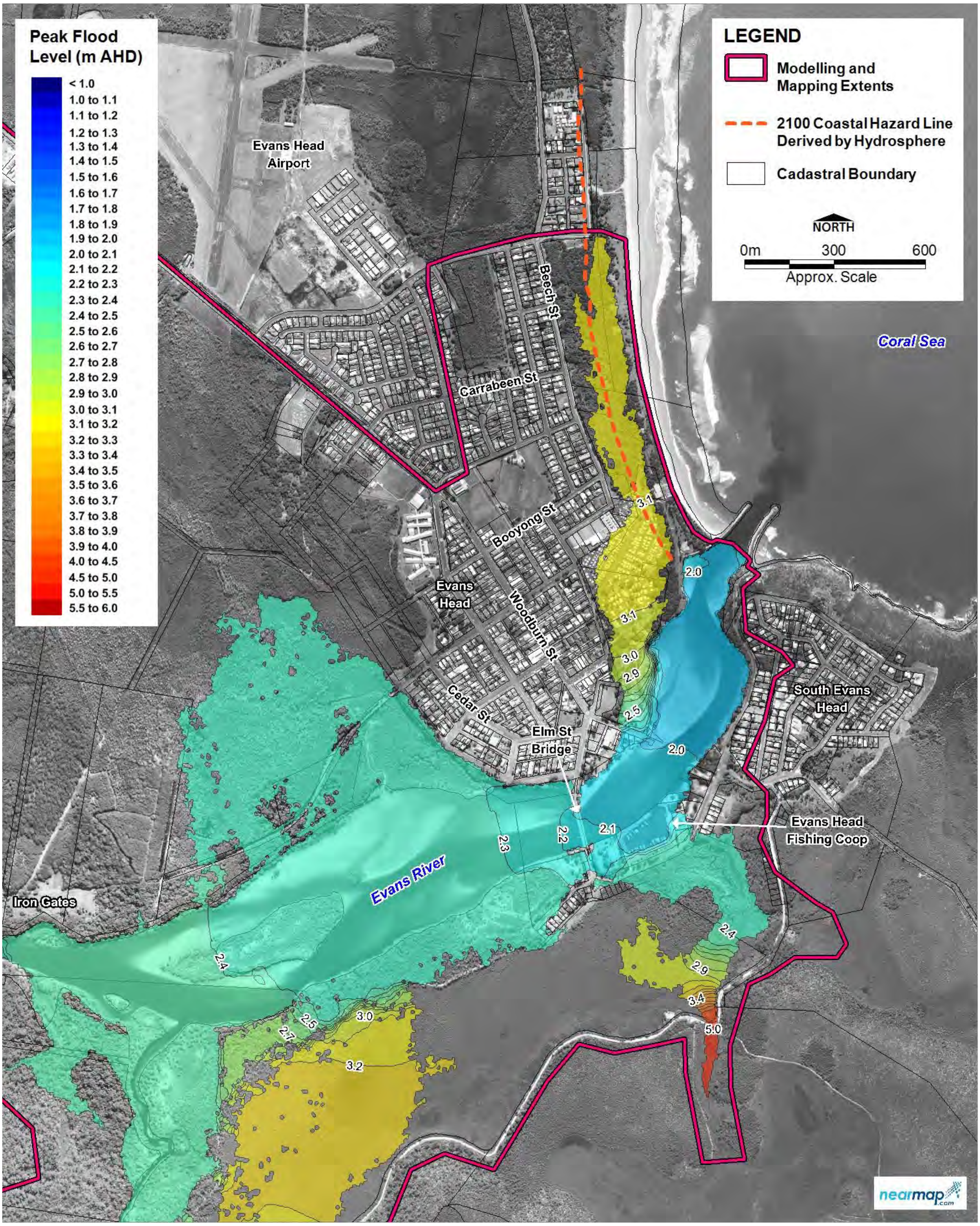

Figure 6-6 100 year ARI Flood Levels (Evans Head)

6.4.2 20 year ARI Flood

Figure 6-7 and Figure 6-8 present the 20 year ARI peak flood levels for the Evans River and Evans Head respectively. Flood levels vary between 3.5m AHD and 4.0m AHD in the upper Evans River floodplain. This causes inundation of a significant extent of floodplain. Within Evans Head the Silver Sands Holiday Park is inundated along with the area surrounding the harbour in South Evans Head. All other areas within Evans Head are raised above the flood levels.

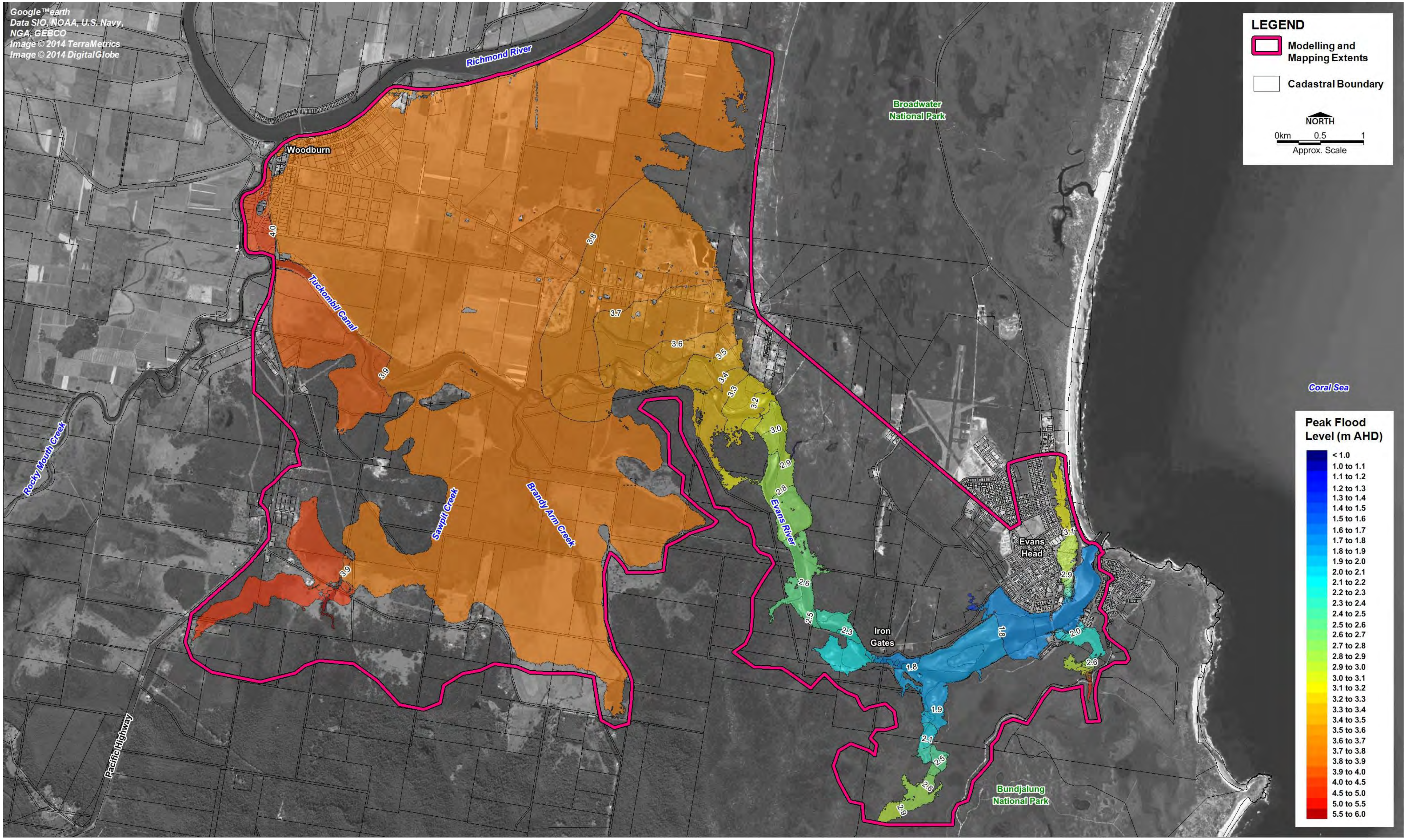

Figure 6-7 20 year ARI Flood Levels

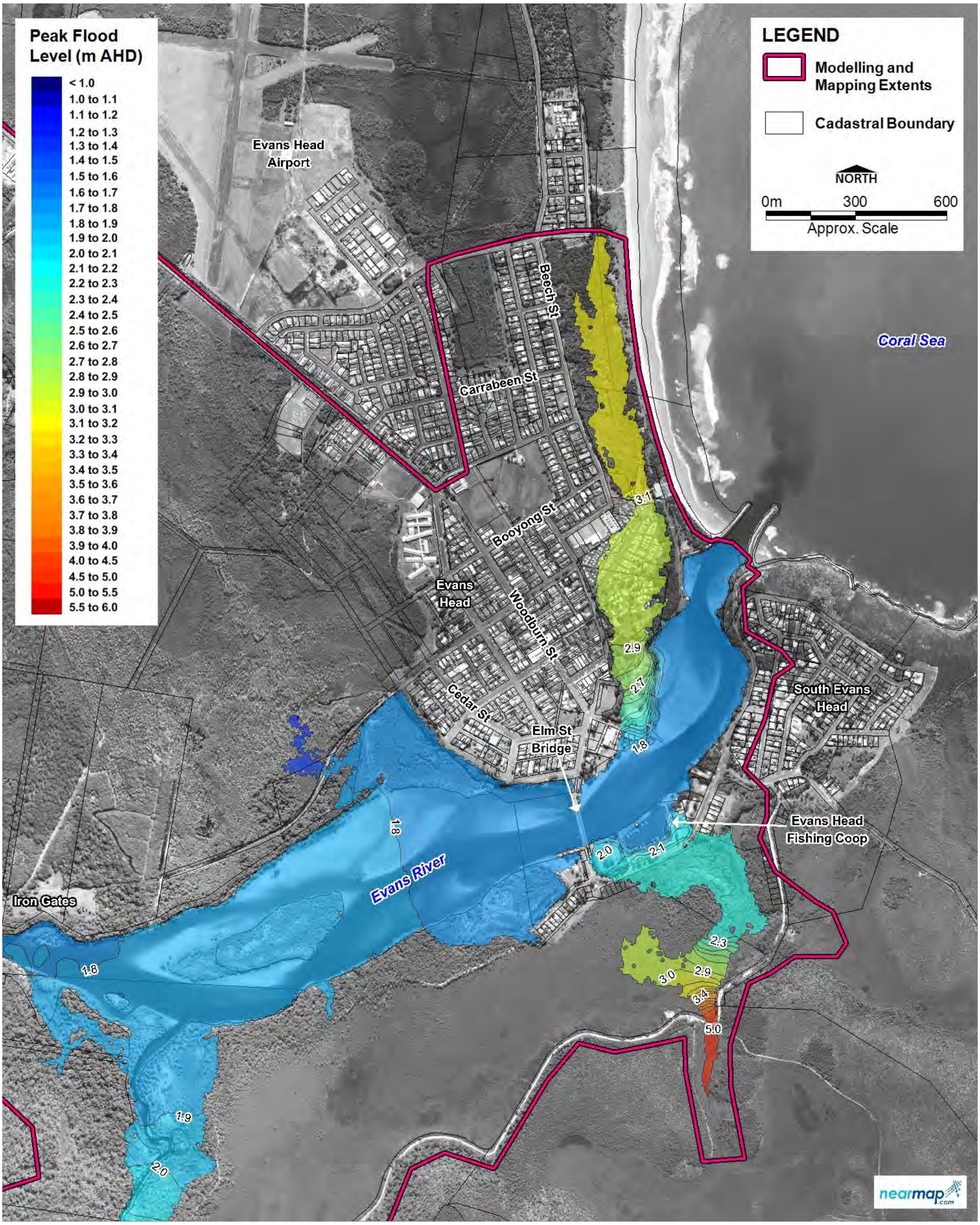

Figure 6-8 20 year ARI Flood Levels (Evans Head)

6.4.3 50 year ARI Flood

Figure 6-9 and Figure 6-10 present the 50 year ARI peak flood levels for the Evans River and Evans Head respectively. Flood levels vary between 4.0m AHD and 4.2m AHD in the upper Evans River floodplain. This causes inundation of a significant extent of floodplain. Within Evans Head the extent of inundation is broadly similar to the 20 year ARI event with the Silver Sands Holiday Park inundated along with the area surrounding the harbour in South Evans Head. All other areas within Evans Head are raised above the flood levels.

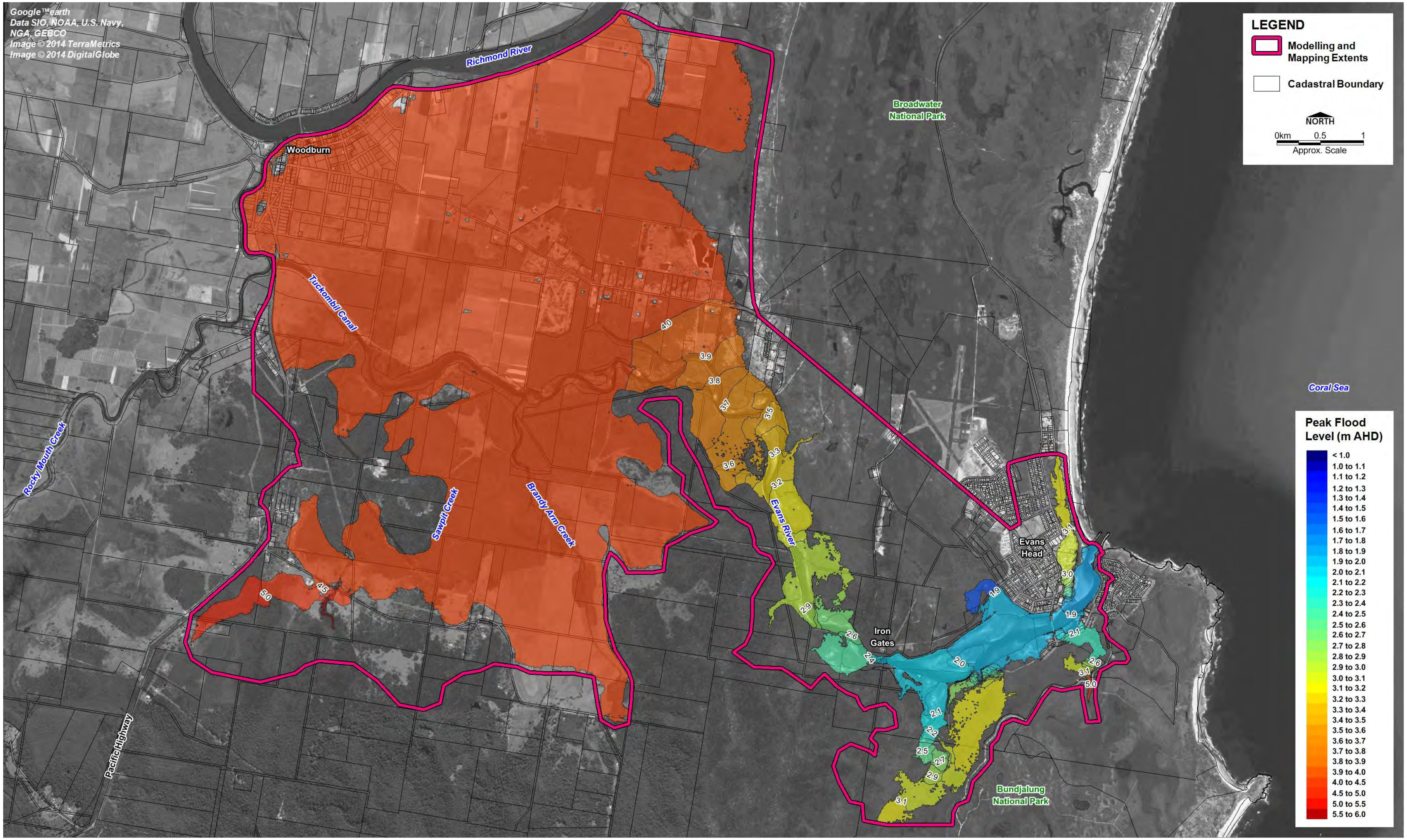

Figure 6-9 50 year ARI Flood Levels

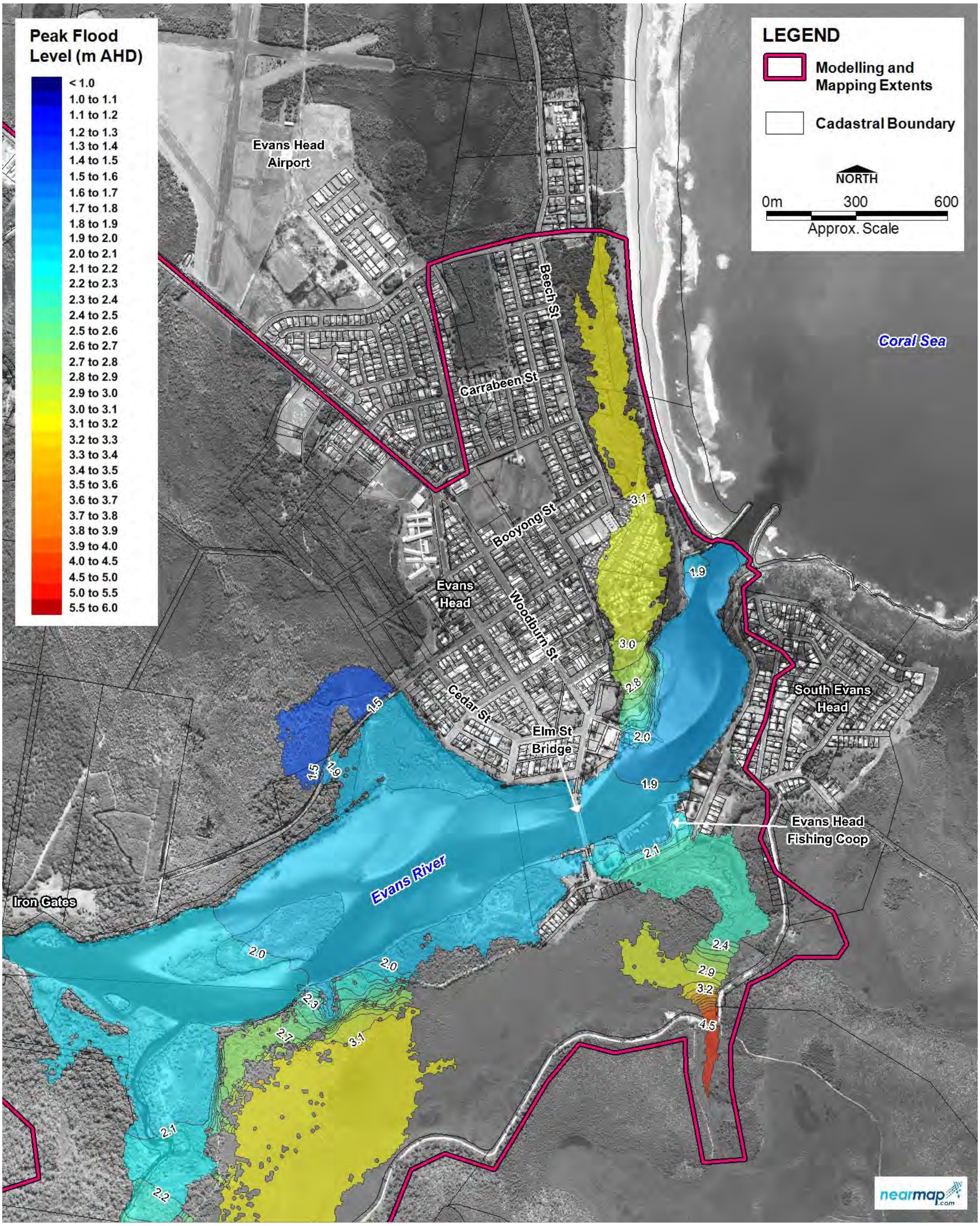

Figure 6-10 50 year ARI Flood Levels (Evans Head)

6.4.4 500 year ARI Flood

Figure 6-11 and Figure 6-12 present the 50 year ARI peak flood levels for the Evans River and Evans Head respectively. Flood levels vary between 5.5m AHD and 5.6m AHD in the upper Evans River floodplain. This causes inundation of a significant extent of floodplain. Within Evans Head the extent of inundation is broadly similar to the 100 year ARI event with the Silver Sands Holiday Park inundated. However the extent of inundation within South Evans Head has increased to include much of Bundjalung Road and Ocean Drive alongside the harbour being inundated. All other areas within Evans Head are raised above the flood levels

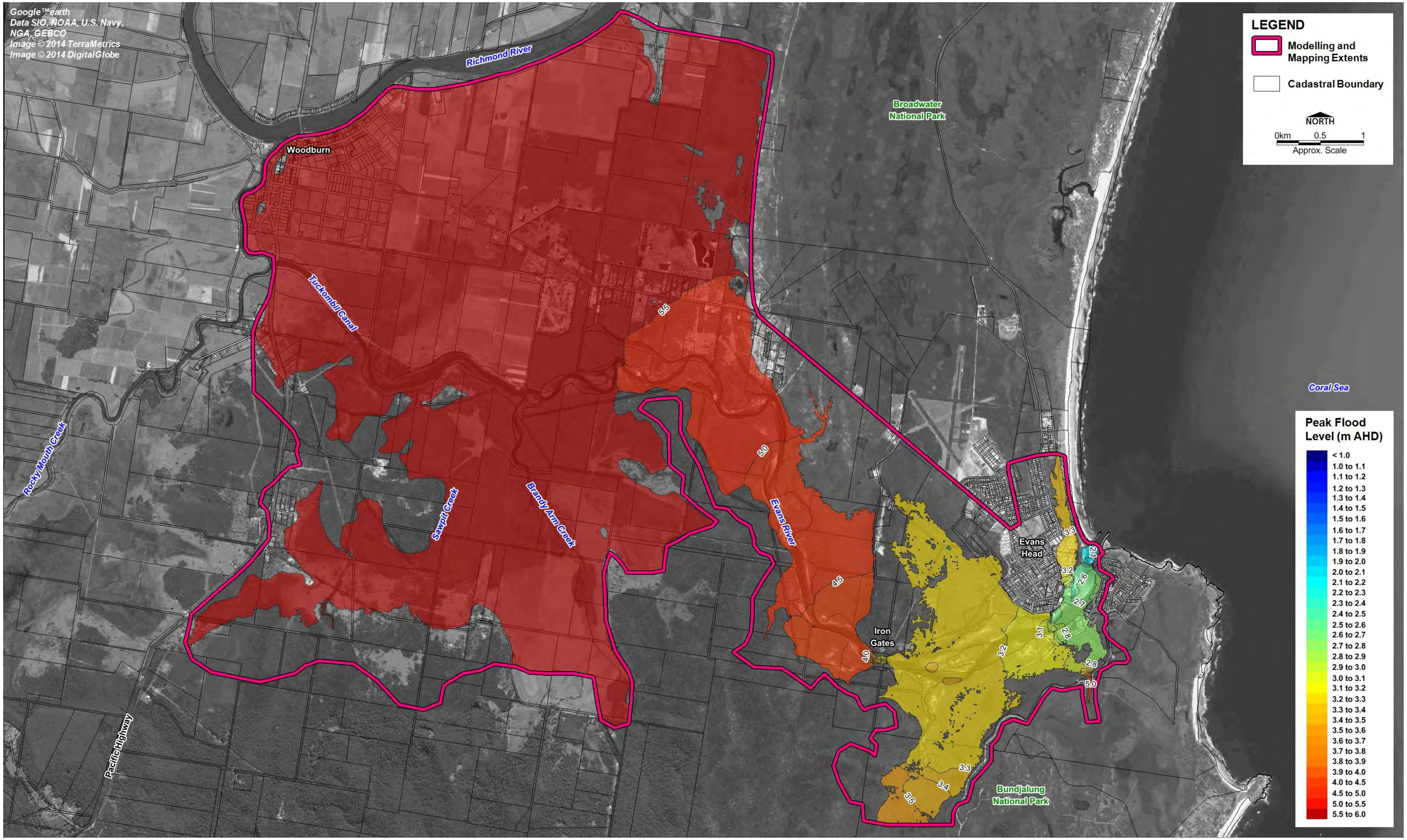

Figure 6-11 500 year ARI Flood Levels

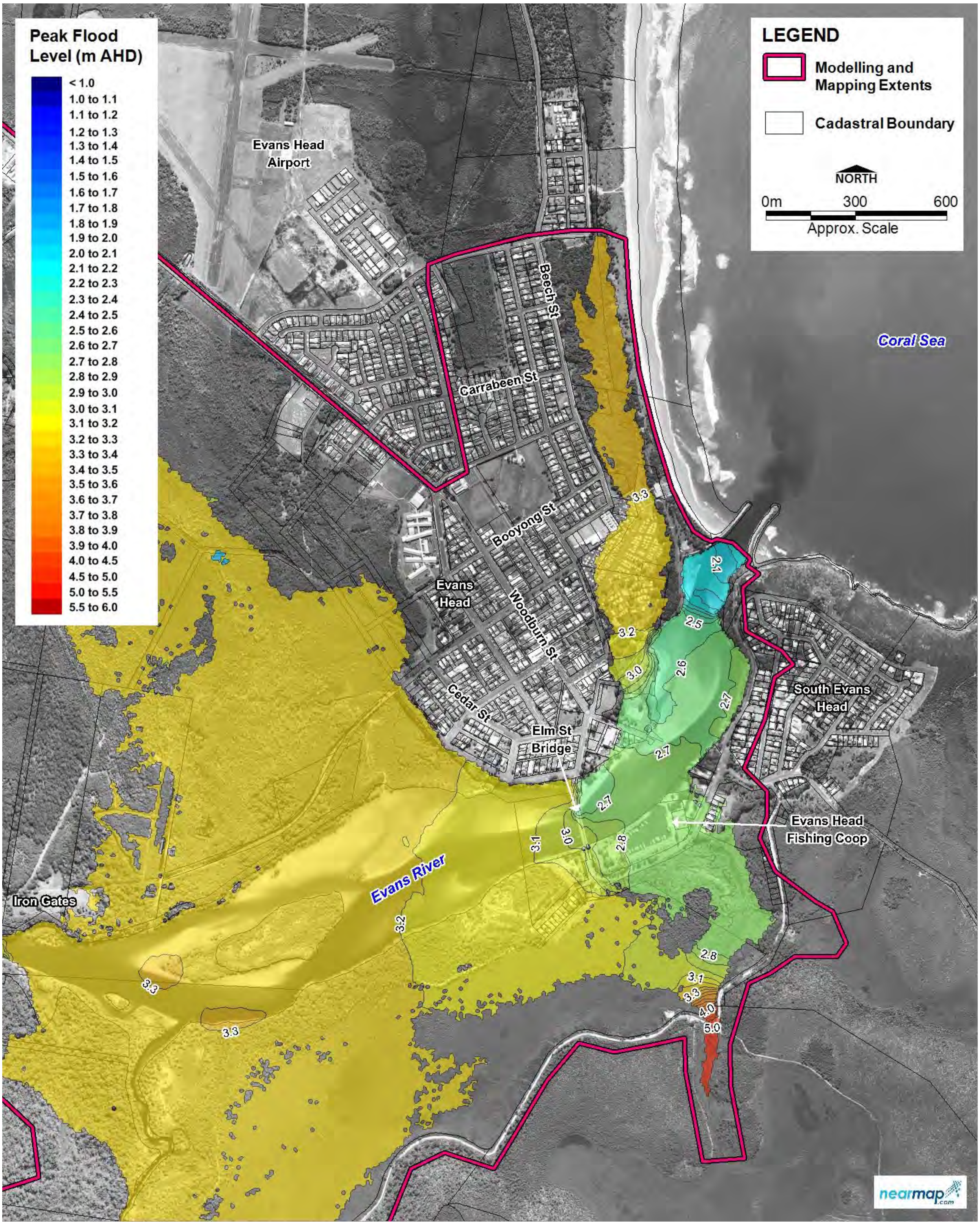

Figure 6-12 500 year ARI Flood Levels (Evans Head)

6.4.5 Probable Maximum Flood

The Probable Maximum Flood (PMF) inflow to the Evans River from the Richmond River is so great that it exceeds the scale of the model and results in exaggerated flood levels. It was clear, however, that the majority of the Evans River catchment, including Evans Head would be inundated during a PMF event. Figure 6-13 shows potentially PMF affected flood prone land based on the topography. It should be noted that this map is not based on hydraulic model output but has instead been informed by the findings form the hydraulic modelling.

The map, whilst conservative, does reflect the extreme nature of the event.

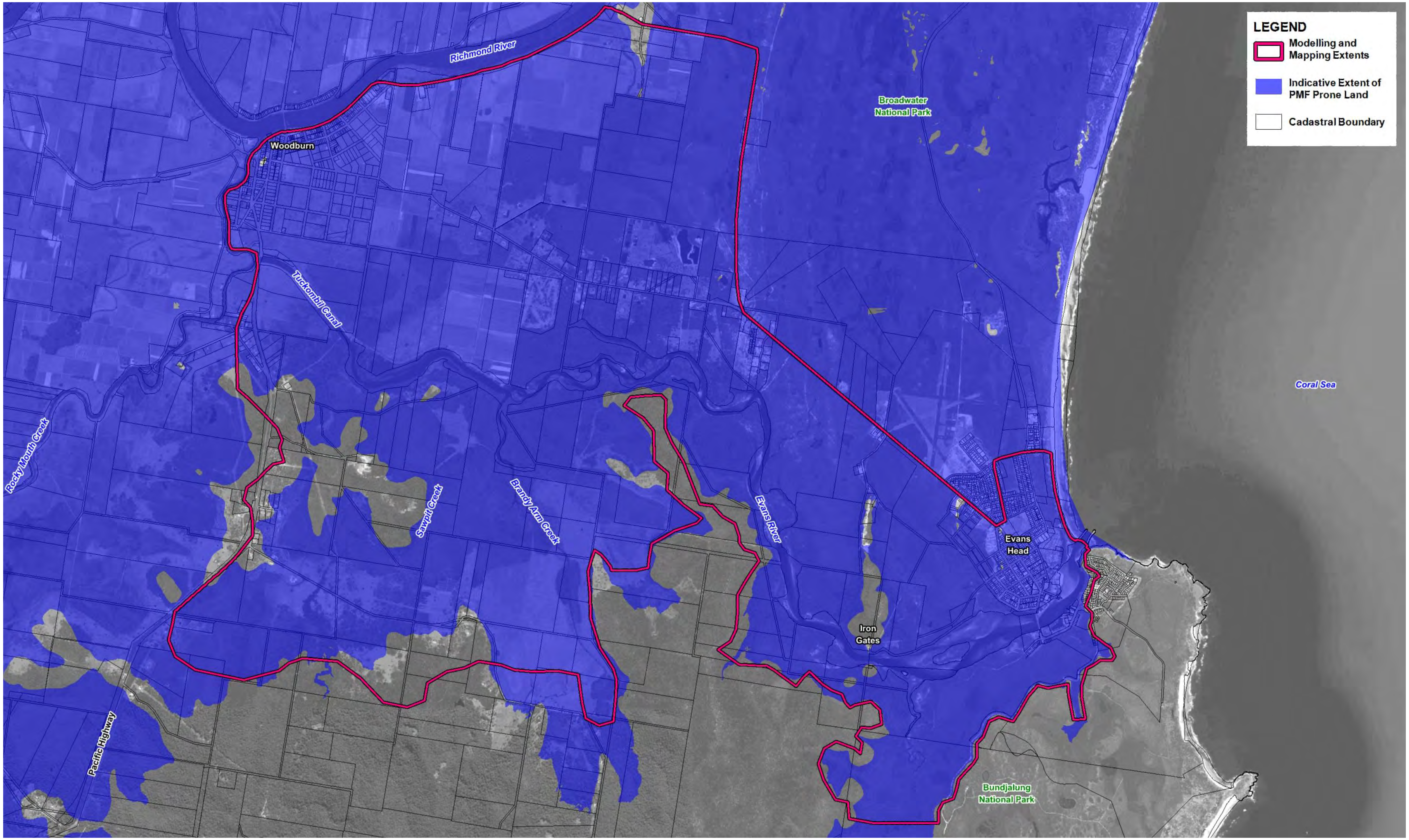

Figure 6-13 Indicative Extent showing PMF Flood Prone Land

6.5 Climate Change Assessment

A climate change sensitivity assessment has been undertaken on the 100 year ARI event by applying a 10% increase in rainfall intensity and a 0.9m rise in sea level. These values are currently used by RVC and are derived from the following New South Wales government guidelines and policy:

- Floodplain Risk Management Guideline: Practical Consideration of Climate Change (DECC, 2007); and
- NSW Sea Level Rise Policy Statement (DECCW, 2009).

While the NSW Government has since abandoned the Sea Level Rise Policy and no longer prescribes state-wide sea level rise projections, Council has not undertaken any scientific investigations of its own and have maintained the 0.9m benchmark used in the 2009 policy. A 10% increase to rainfall intensity has also been adopted.

Additional climate change sensitivity assessments were undertaken for the 20, 50 and 500 year ARI events but these only included the 0.9m sea level rise and not the additional 10% rainfall intensity increase. This was due to the dominance of the tidal component over the riverine component in determining the peak flood levels at Evans Head.

Figure 6-14 presents the peak flood levels for the 100 year ARI event under a future climate. Figure 6-15 shows the same data but presented for Evans Head. It can be seen that peak flood levels increase at Evans Head by approximately the same increase applied in the sea level (0.9m). The majority of Evans Head remains at a sufficient elevation to be located above this future 100 year ARI flood level. A notable exception is for areas in South Evans Head near the harbour, Ocean Drive and Bundjalung Road which are now subject to greater inundation.

Figure 6-16 to Figure 6-18 present peak flood levels in Evans Head for the 20, 50 and 500 year ARI events respectively.

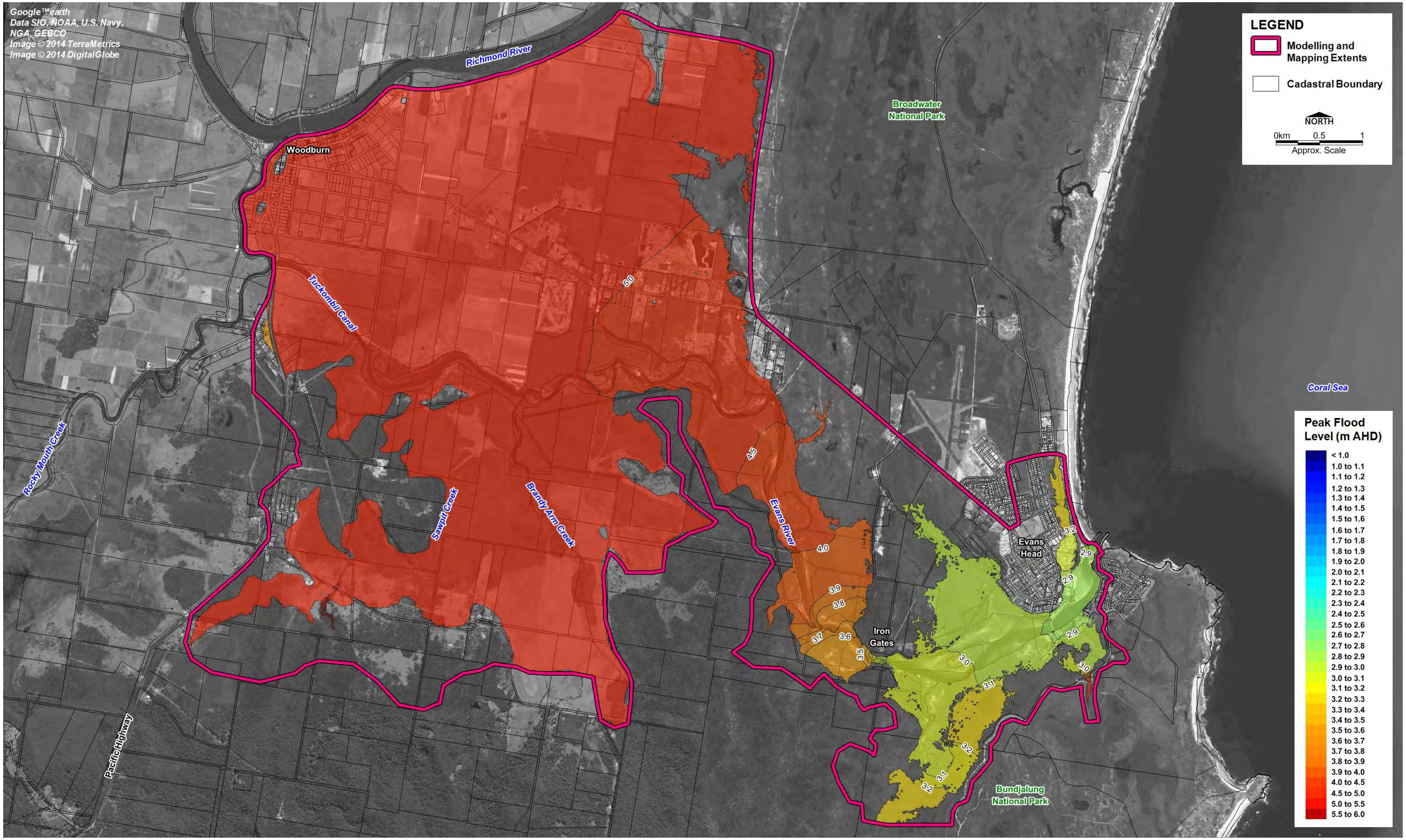

Figure 6-14 100 year ARI Levels Climate Change Assessment

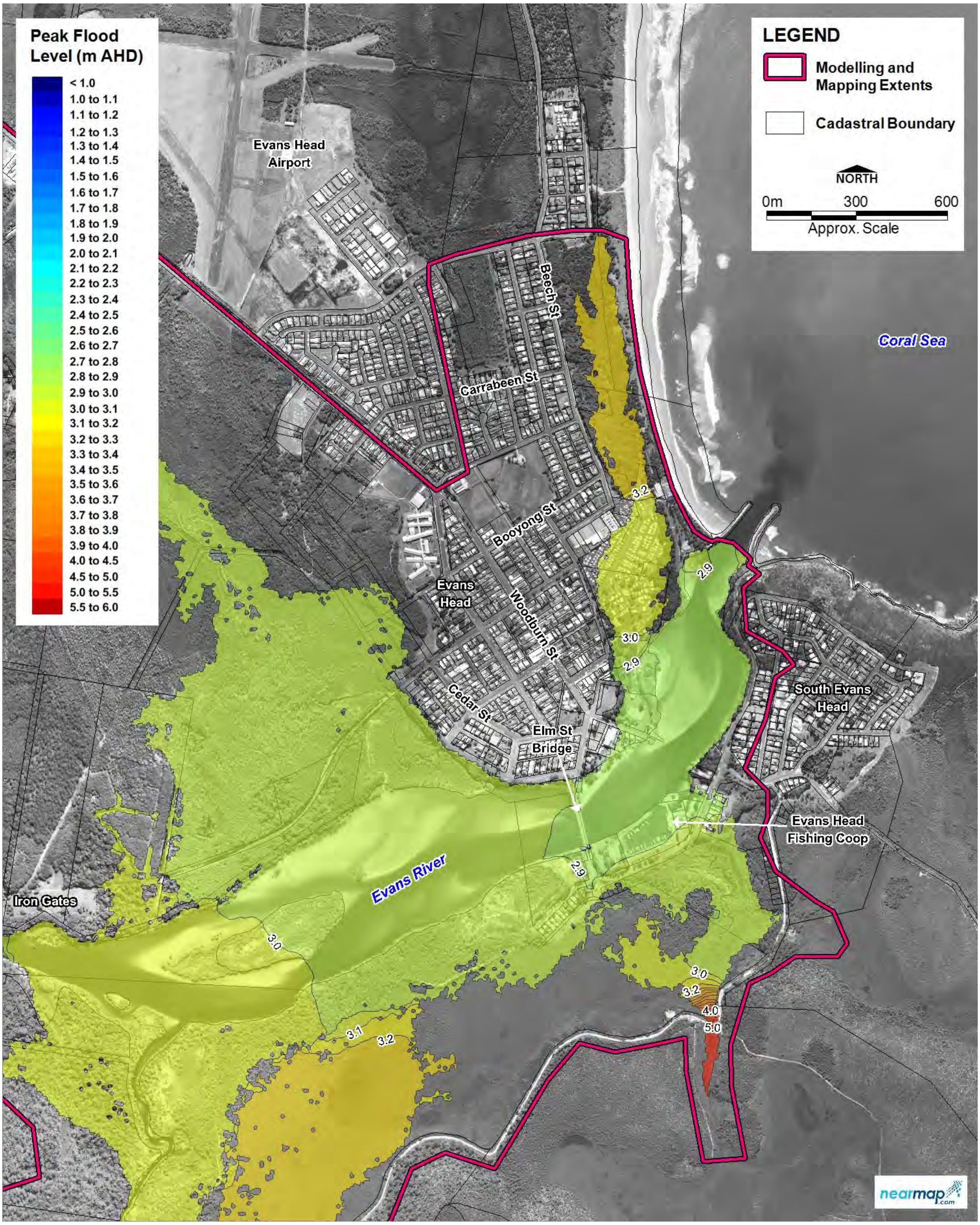

Figure 6-15 100 year ARI Levels Climate Change Assessment – Evans Head

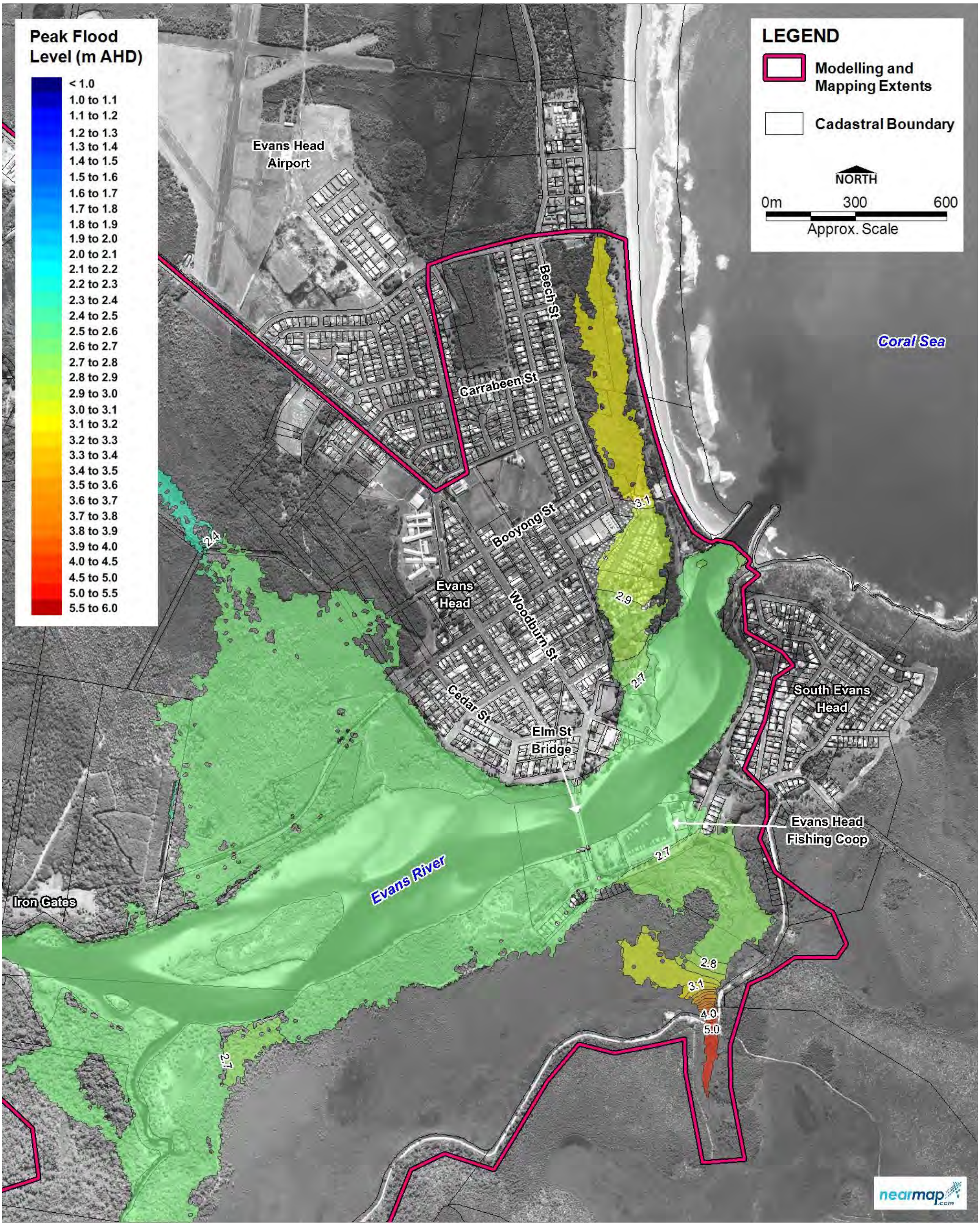

Figure 6-16 20 year ARI Levels Climate Change Assessment – Evans Head

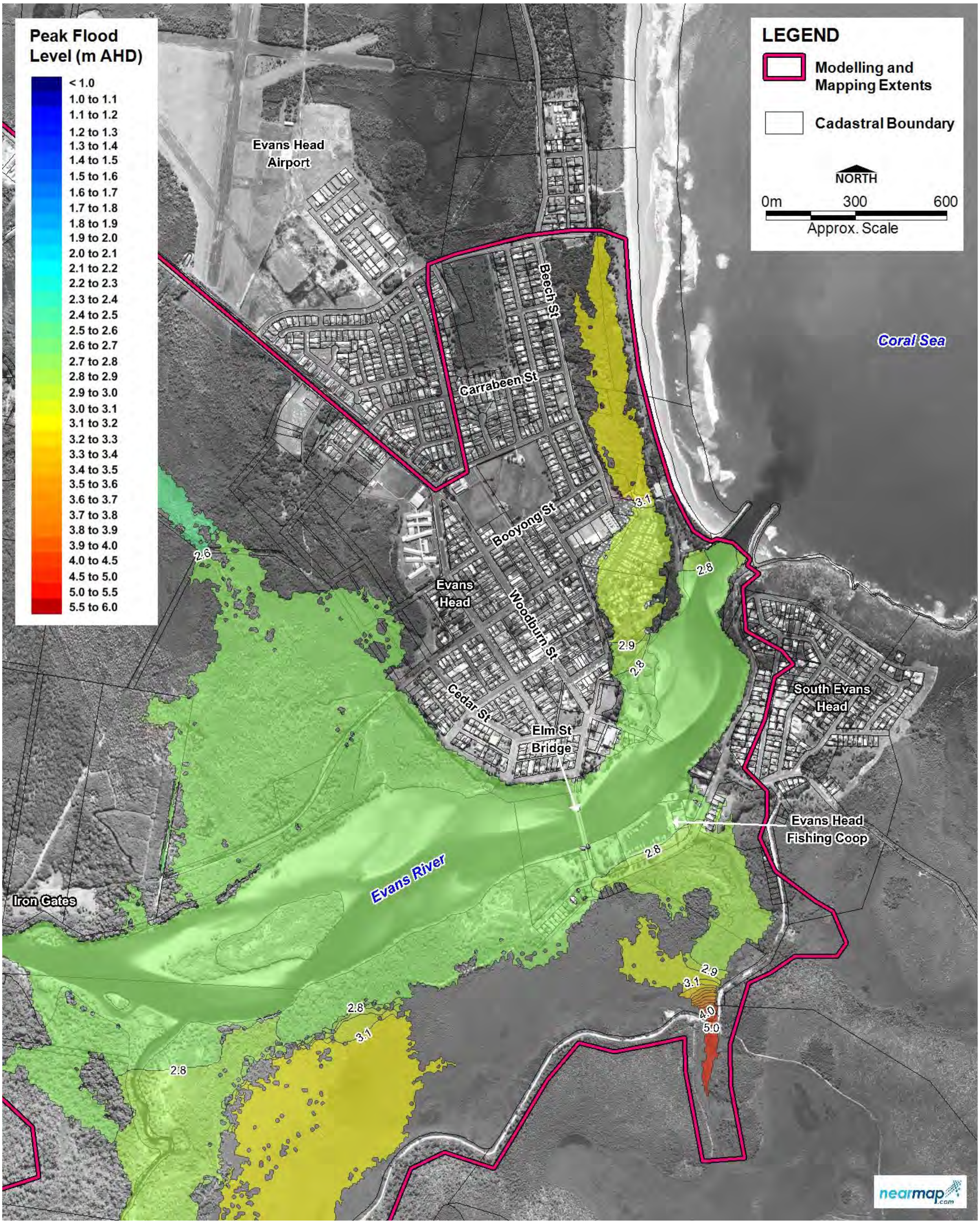

Figure 6-17 50 year ARI Levels Climate Change Assessment – Evans Head

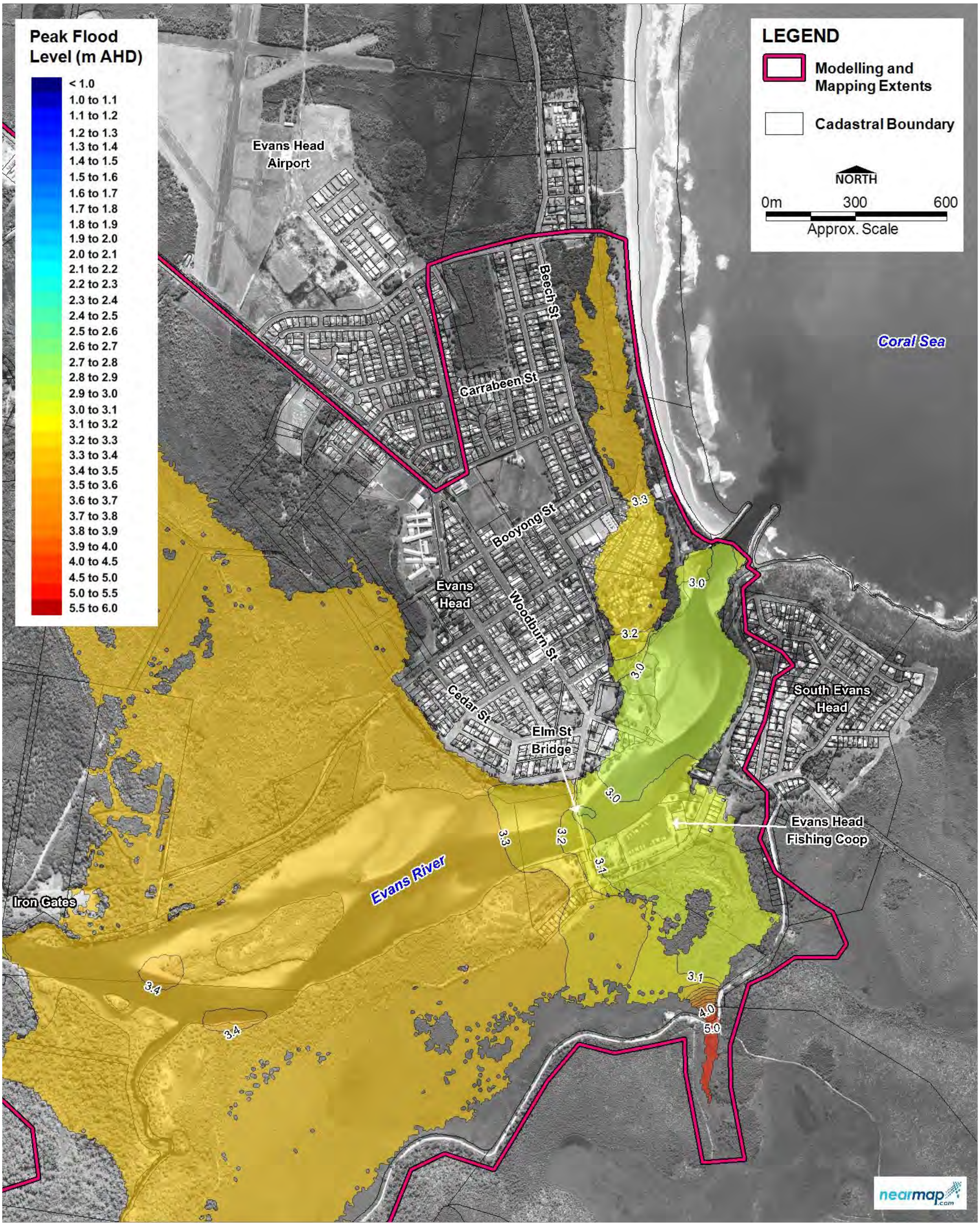

Figure 6-18 500 year ARI Levels Climate Change Assessment – Evans Head

6.6 Additional Assessments

6.6.1 Travel Time Assessment

In order to assess the travel time of the peak flood as it passes along Evans River it was necessary to remove the time varying tidal boundary component and replace it with a static boundary level set to 0m AHD. In this way the signal of the flood wave was clearly distinguishable at the downstream end of the model where the tidal signal dominates. A map showing the resulting 100 year ARI peak levels along with indicative travel times along the Evans River is presented in Figure 6-20. It can be seen that total travel time from the Tuckombil Weir to Evans Head is approximately 5 hours. It should be noted that flooding at Evans Head will only occur on the high tides, with flood waters subsiding during the low tide, before rising again with the next high tide. Therefore, the 5 hour travel time of the flood from the Tuckombil Weir will actually depend upon the tide at the time of the flood.

6.6.2 Floodplain Constrictions

A long section plot of the 100 year ARI flood event without the tidal component is presented in Figure 6-19. The tidal component was removed so that the plot clearly shows the influence of any floodplain constrictions on the propagation of the riverine flood. It can be seen from Figure 6-19 that two major constrictions are present which affect peak flood levels during riverine flood events; Iron Gates and the Breakwater. By comparison Elm Street Bridge is a relatively minor constriction.

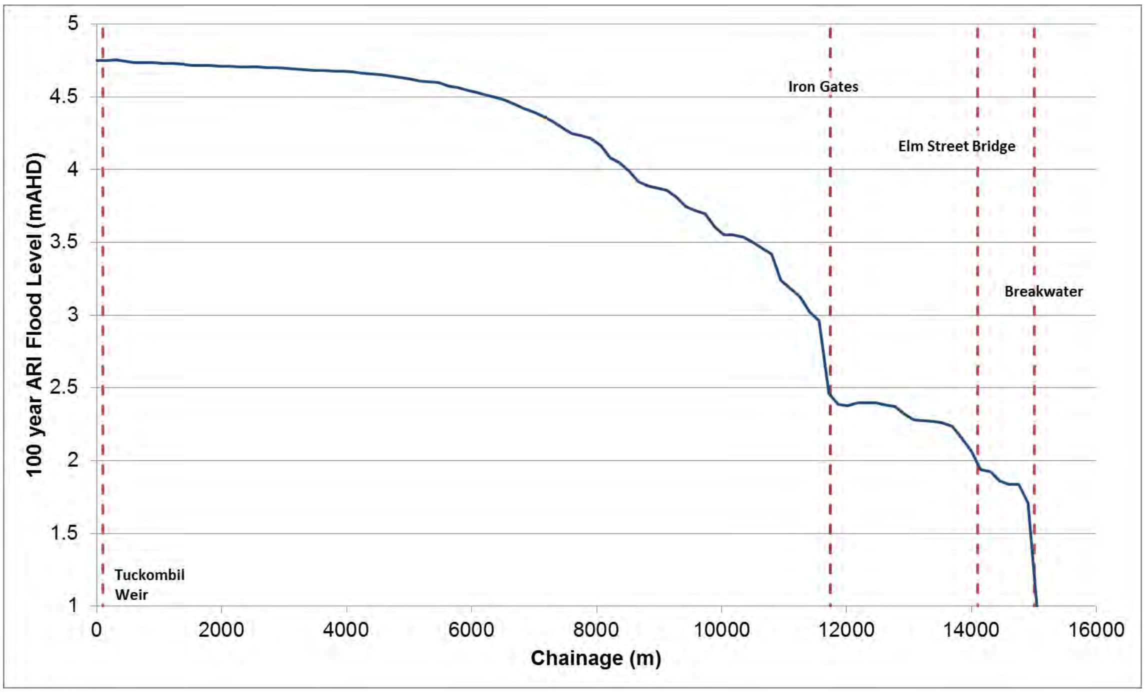

Figure 6-19 100 year ARI Long Section Plot

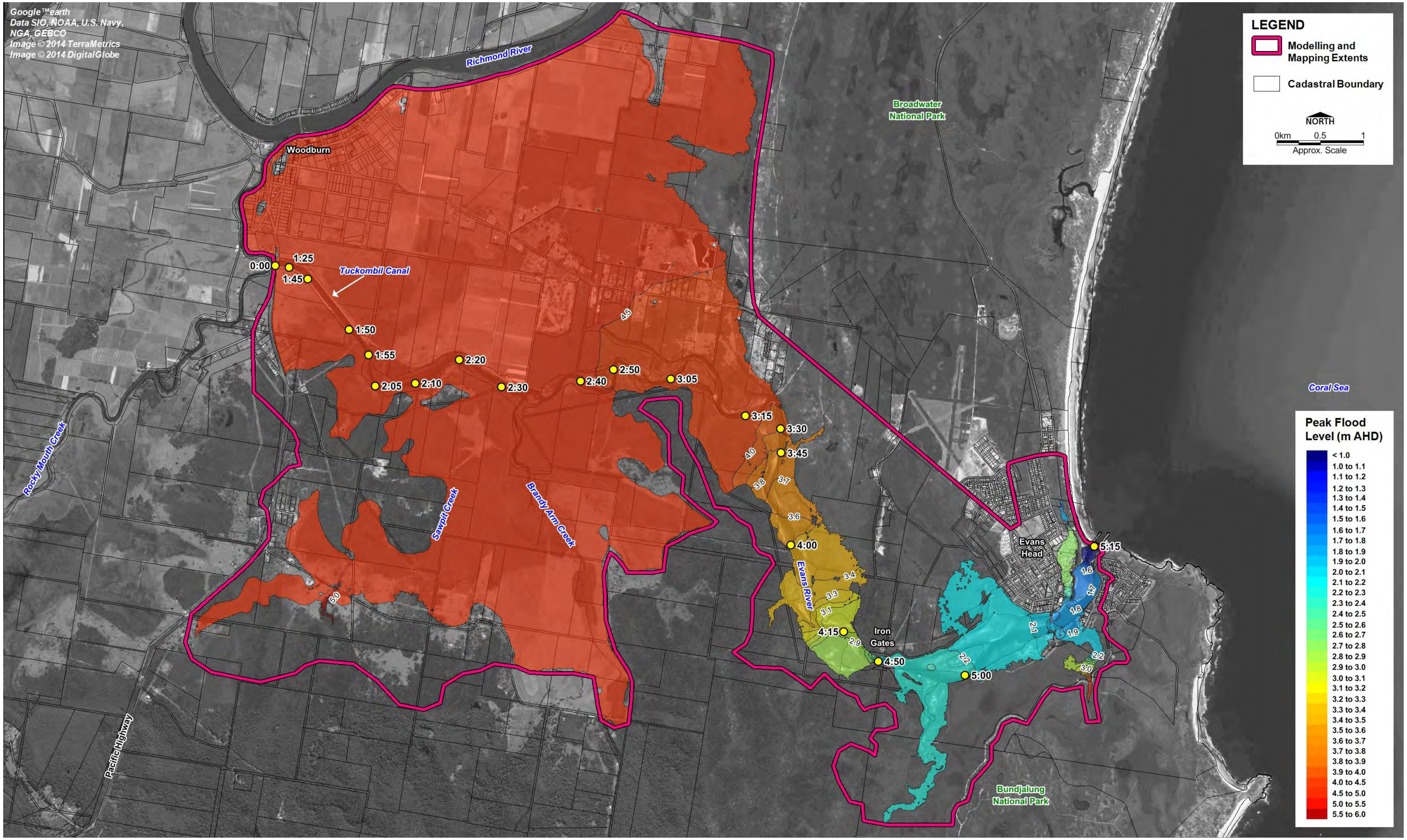

Figure 6-20 100 year Approximate Travel Times along the Evans River

6.6.3 Local Runoff Event

A 100 year ARI local runoff event was assessed to determine whether a short, intense burst of rainfall could, in places, result in higher flood levels than the modelled design events. This local event was modelled with a particular focus on the unnamed drainage channel within Evans Head that flows through the holiday park. A king tide event was simulated to occurred at the same time as a 100 year ARI 3 hour storm event. At all places except for the headwaters of tributaries joining Evans River, it was predicted that peak flood levels were lower than for the design events used in this study (100 year ARI, 72 hour storm). For these reasons a map of the local flood event has not been prepared.

6.6.4 Sensitivity of Tuckombil Weir Elevation

The Tuckombil weir is set to a fixed elevation of 0.94m AHD. A sensitivity assessment was undertaken to assess the impact on drainage times (upstream of the weir) if the weir was lowered by 0.2m to an elevation of 0.74m AHD. The RRFMS model was used for this assessment as the upstream boundary of the Evans River model was too close to the weir to permit a valid sensitivity assessment in that model.

Figure 6-21 shows the effect of changing the weir elevation on drainage times for the 20 year ARI event. The hydrograph is plotted at Rocky Mouth Creek immediately upstream of Tuckombil Canal. It can be seen that the changes in flood level and therefore drainage times are negligible and that during flood events the 0.2m height change in the weir level is insignificant.

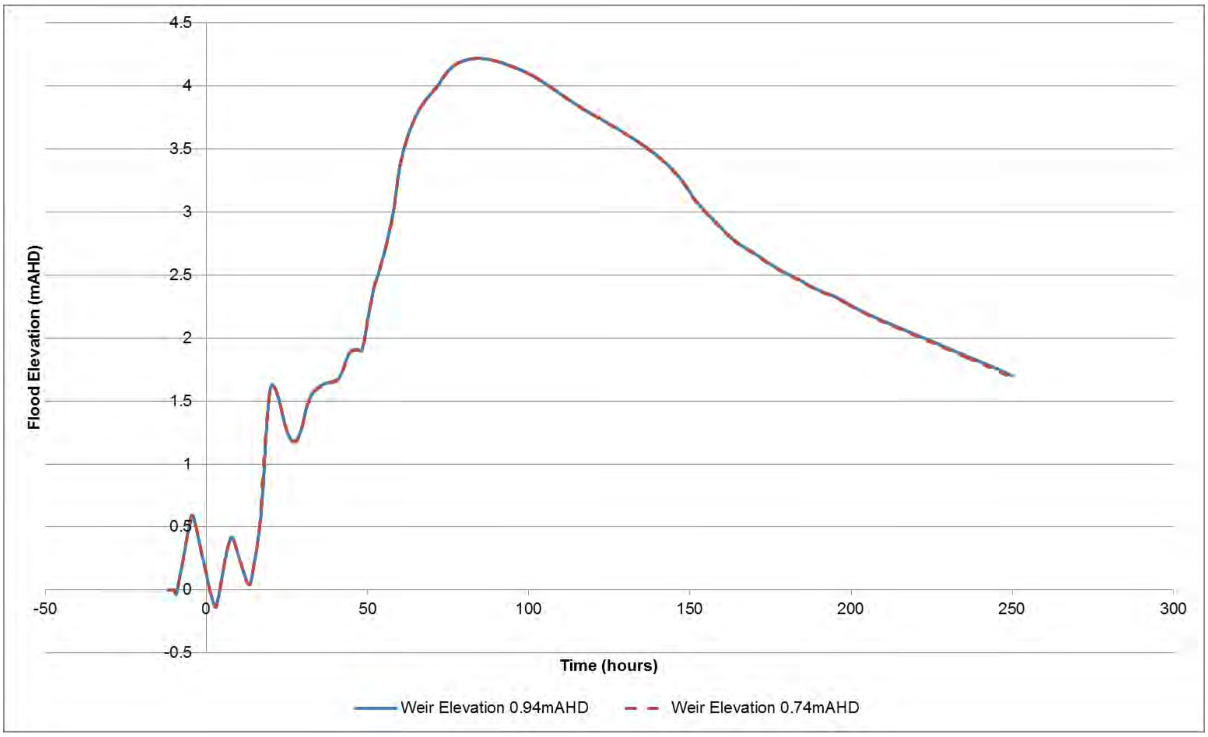

Figure 6-21 Evans River Sensitivity to Weir Height (20 year ARI)

7 Conclusions

The following key conclusions have been made from this study:

- The dominant source of flooding to the upper Evans River (Tuckombil area) is from overflows from the Richmond River.
- At Evans Head the main flood risk is from storm surge. However, much of Evans Head is at elevations sufficient to be above the 100 year ARI storm surge level.
- Peak 100 year ARI flood elevations at Evans Head typically range between 2.0m AHD and 2.3m AHD.
- Silver Sands Holiday Park within Evans Head and low lying parts of South Evans Head along Ocean Drive and Bundjalung Road are at risk from flooding in a 100 year ARI event.
- A climate change assessment was undertaken with a 10% increase in rainfall intensity and a 0.9m rise in sea level. This showed that whilst flood depths increased significantly in the Evans River, the overall 100 year ARI flood extent within Evans Head did not notably change with the exception of some additional inundation along Ocean Drive and Bundjalung Road.
- A local, short duration, high intensity rainfall event across the Evans River does not result in higher flood levels than for when a Richmond River event passes through the Evans River catchment.
- The approximate travel time of a significant flood peak (100 year ARI event) between the Tuckombil Weir and Evans Head is around 5 hours.
- A sensitivity assessment of lowering the Tuckombil Weir level from 0.94m AHD to 0.74m AHD showed that the change in elevation was insignificant on the flooding response of the river for the 20 year ARI event.

Appendix A Model and Results Files

The supplied DVD contains TUFLOW model files and max asc grid result files for the 20, 50, 100 and 500 year ARI design flood events. Climate change models and results are also included.

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Our Ref: : L.B19079.012_Iron_Gates.docx

22 August 2014

Gold Coral Pty Ltd
c/o Planit Consulting
Level 2, 11-13 Pearl Street
Kingscliff
NSW 2487

Attention: Adam Smith

Dear Adam

RE: ASSESSMENT OF LOCAL RUNOFF FOR THE IRON GATES DEVELOPMENT

This letter has been prepared at the request of Planit Consulting, acting on behalf of Gold Coral Pty Ltd, to assess the impact of runoff from the proposed Iron Gates development site. The main focus of this assessment is whether on-site detention of runoff is required to protect downstream properties.

Background of Flood Modelling

In 2010, BMT WBM prepared the *Richmond River Flood Mapping Study* (RRFMS) for Richmond Valley Council and Richmond River County Council. A major component of that study was the preparation of regional hydrologic and hydraulic models. In 2012, on behalf of the Ingles Group, BMT WBM extended the RRFMS flood model down the Evans River to the river mouth at Evans Head. The purpose of that assessment was to assess the flood risk for the Iron Gates development as well as any potential flood impact. In 2014, BMT WBM prepared the *Evans River Flood Study* (ERFS) for Richmond River County Council. For that study, a new flood model of the Evans River was prepared, incorporating more recent topographic survey than used in the RRFMS. The new Evans River model was higher resolution than any previous modelling, and represented the Evans River system using a two-dimensional grid[1].

Peak flood levels adjacent to the Iron Gates development site are consistent between the 2012 flood assessment and the recent Evans River Flood Study. Peak 100 year ARI flood levels are shown in Table 1, together with the corresponding climate change scenario flood levels.

Table 1 100 year ARI flood levels at the Iron Gates site

	100 Year ARI Flood Level	100 Year ARI Flood Level including Climate Change
Iron Gates Flood Assessment (2012)	2.5m AHD	3.0m AHD
Evans River Flood Study (2014)	2.5m AHD	3.1m AHD

[1] The RRFMS flood model used a 1D representation of the Evans River past Iron Gates, whereas the 2012 Iron Gates Flood Assessment model used an integrated 1D/2D approach.

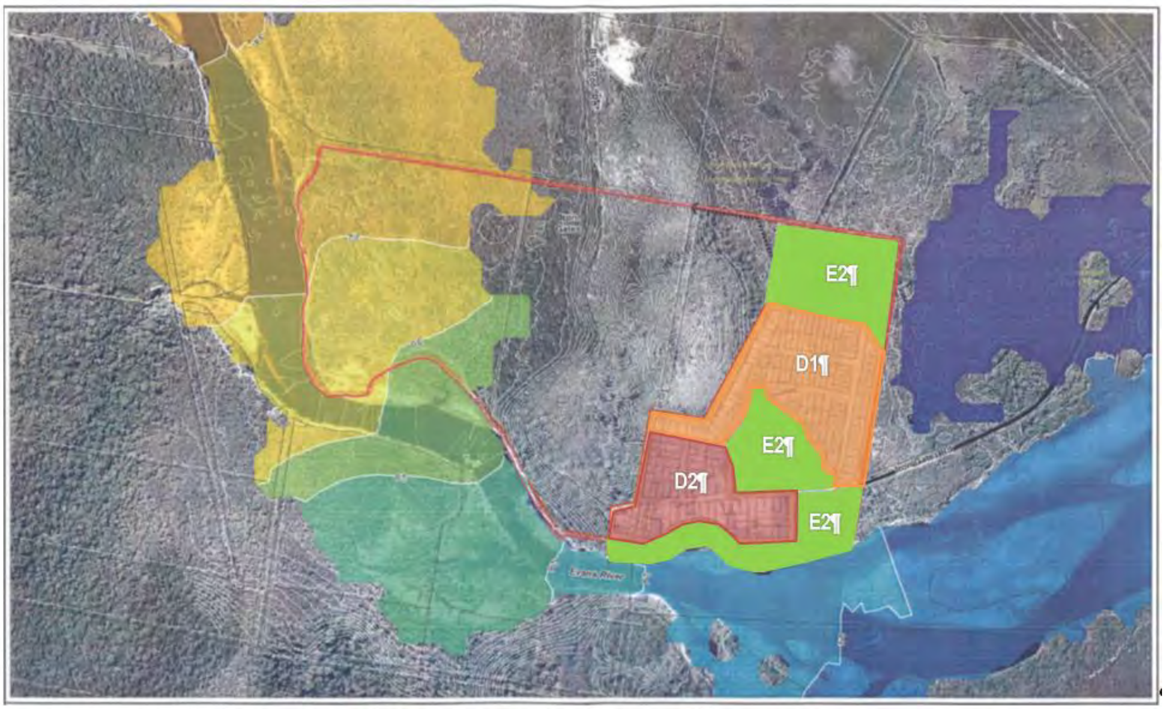

Figure 1 Proposed Iron Gates development site

Of relevance to this assessment, the following conclusions are listed in the ERFS report (ref. R.B2500.001.02.Main_Report):

- *At Evans Head the main flood risk is from storm surge. However, much of Evans Head is at elevations sufficient to be above the 100 year ARI storm surge level.*
- *A climate change assessment was undertaken with a 10% increase in rainfall intensity and a 0.9m rise in sea level. This showed that whilst flood depths increased significantly in the Evans River, the overall 100 year ARI flood extent within Evans Head did not notably change with the exception of some additional inundation along Ocean Drive and Bundjalung Road.*
- *A local, short duration, high intensity rainfall event across the Evans River does not result in higher flood levels than for when a Richmond River event passes through the Evans River catchment.*
- *The approximate travel time of a significant flood peak (100 year ARI event) between the Tuckombil Weir and Evans Head is around 5 hours.*

For this assessment, three flood / runoff scenarios are discussed:

- Regional flooding from the Richmond River;
- Evans River catchment flooding; and
- Storm surge.

Regional Flooding from the Richmond River

During significant flood events, floodwaters in the Richmond River and Rocky Mouth Creek overtop the Tuckombil Canal and enter the Evans River. This mechanism of flooding poses the greatest risk to the Evans River catchment, in terms of peak flood levels and flows. Typically, the response time of the Richmond River at the Tuckombil Canal is greater than 2 days, meaning that flooding in the Mid-Richmond area will typically occur days after the main rainfall. The critical duration assessment of the Richmond River also shows the highest flood levels at the Tuckombil Canal to be the 72 hour design event. As shown during previous studies, whilst these floods pose the greatest risk to the Evans River catchment, peak 100 year ARI flood levels are still below the ground elevation of the development site.

Shown in Figure 1 is the flood hydrograph (flood level vs time) in the Evans River adjacent to the site, resulting from a 100 year ARI 72 hour duration Richmond River Flood (blue line). The hydrograph shows the peak occurring at 91 hours simulation time, with a smaller peak occurring on the high tide the day before at 67 hours simulation time. The local runoff from the sub-catchment incorporating the Iron Gates development is shown as the red line. The primary point of interest from this figure is the correlation between the two time series. As runoff from the local catchments enters the Evans River, there is a series of minor rises in river level. The peaks shown at 5, 17, 29, 42, 55 hours simulation time, are actually a result of the storm surge, rather than the local runoff. However, the magnitude of the peaks is determined by the volume of water in the system due to local runoff. This can be seen by looking at the low tides between these peaks, where the peak flood level remains above 0.6m AHD following the start of the storm. The local runoff is generally drained with each falling tide, always resulting in the low tide flood level being below 1.0m AHD.

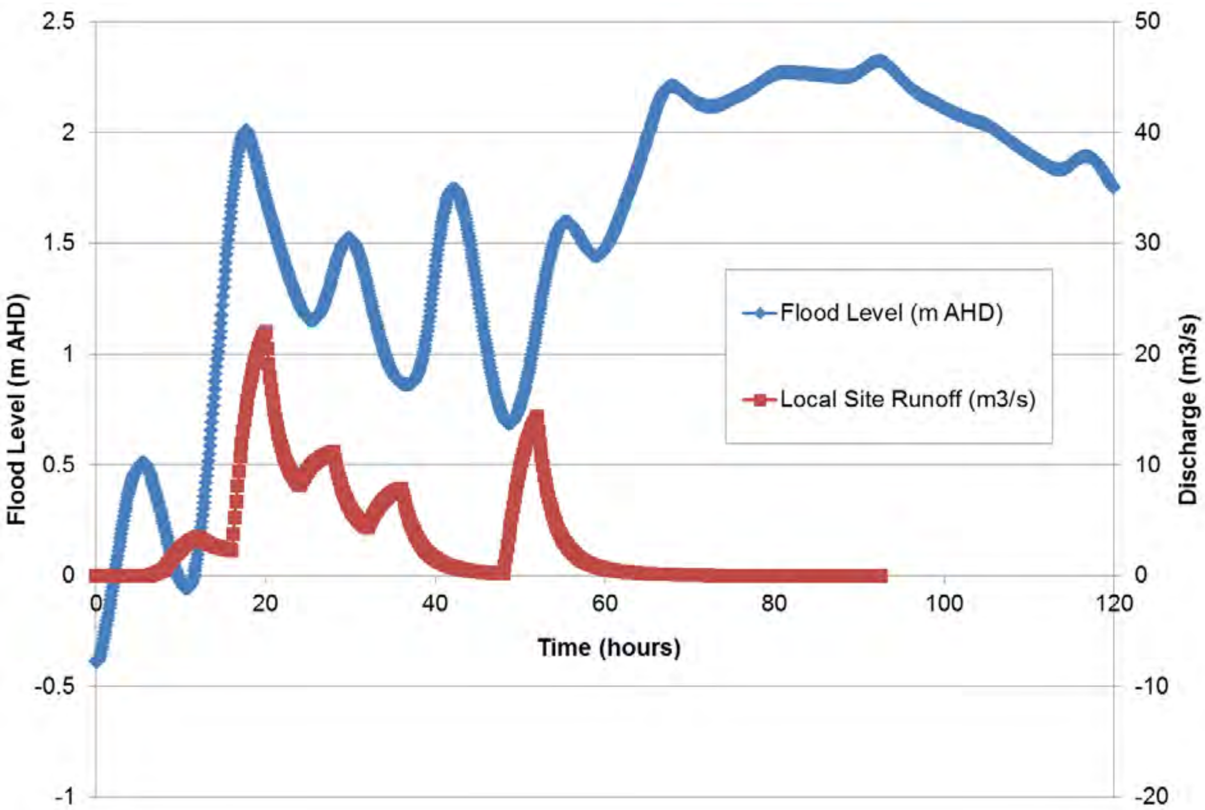

Figure 2 Richmond River and Local Catchment runoff timing

Following the local catchment runoff, the Tuckombil Canal overtops and the Richmond River flood flushes through the Evans River system. This can be seen on Figure 1 by the major flood levels occurring after 60 hours simulation time. During the Richmond River flush, flood levels remain above 1.5m for nearly 3 days. During this time, whilst the tide is having an influence on the discharge from the system, it is not having a significant effect on flood levels.

In order to minimise the peak flood levels, it is important to allow as much of the local runoff to drain from the Evans River system prior to the Richmond River flood flushing through.

Evans River Catchment Flooding

Flooding from the Evans River catchment follows the same trend, albeit on shorter timescale and with lower flood levels. The local catchment runoff enters the Evans River and drains with the next receding tide. This is then followed by the Upper Evans River catchment runoff flowing along the Evans River through the Iron Gates.

Storm Surge Flooding

Storm surge has been incorporated into the various modelling simulations undertaken for all flood assessments on the Evans River. Storm surge in isolation from rainfall does not pose a risk to the development site. The various simulations undertaken have included storm surge both with and without an allowance for sea level rise. The presence of storm surge at the tidal boundary does not influence the relative timings of the local catchment runoff, Evans River catchment runoff and the Richmond River runoff.

Development Scenarios

The following development scenarios have been considered in terms of their effect on peak flows in the Evans River.

- Entire site development – Catchments D1 and D2 considered to be fully developed without detention basins and environmental areas E2, undeveloped
- Partial site development – Catchment D2 to detain flows to pre-development peak; Catchments D1 developed without detention basin and environmental areas E2 undeveloped.

The WBNM hydrologic model has been updated to include these development scenarios. The outcome from the assessment is that whilst there is an increase in local runoff from the development, in the context of the broader river system, these changes are not noticeable. The fully developed site results in a change to the local sub-catchment (draining western half of Evans Head and the low land to the east of the Iron Gates Ridge) of less than 5%. In terms of the Evans River catchment, this change is less than 0.3% of the area.

This minor change has no influence on peak discharge rates and peak flood levels in the Evans River.

Concluding Remarks

The use of on-site detention (OSD) to mitigate post development peak discharge to pre-development rates is well considered best management practice. However, in some scenarios, the application of OSD is counter-productive. In such cases, consideration must be given on a merit based approach, as recommended in the NSW Floodplain Development Manual.

The Iron Gates development is a good example for not using OSD to manage discharge rates. The proximity of the development to the river mouth means that the traditional 'rapid disposal' method is more applicable. By directly discharging runoff into the river, the water can be drained from the Evans River system with the receding tide. Most runoff will then be drained prior to the larger, regional flows passing through the Evans River, either from Upper Evans River catchment runoff or from Richmond River overflow.

Therefore, BMT WBM recommends against using OSD to delay the release of floodwaters from the proposed development site.

Should you wish to discuss the contents of this letter or require any additional information, please call the undersigned on 07 3831 6744.

BMT WBM Pty Ltd

Ben Caddis

Associate
Senior Flood Engineer